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THE FEASIBILITY OF IMPLEMENTING
VIDEOTELECONFERENCING SYSTEMS
ABOARD AFLOAT NAVAL UNITS

by

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The Feasibility of Implementing Videoteleconferencing Systems Aboard Afloat Naval Units

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ABSTRACT

This study assesses the feasibility of implementing videoteleconferencing systems aboard afloat naval units to support operational reporting, strategy planning, and intelligence sharing requirements.

The information richness that videoteleconferencing (VTC) can provide as a substitute for face-to-face meetings would be extremely valuable to senior afloat commanders, particularly when involved in highly ambiguous situations. This study examines the system components and available commercial and military satellite networks like the Defense Commercial Telecommunications Network that can provide the necessary connectivity with fleet commanders ashore. Afloat user requirements are discussed and illustrated by two peacetime scenarios showing the benefit of using VTC systems. An overview of a proposed VTC system installation is provided to illustrate how a system may be installed within the space and weight limitations aboard ship. Finally, the concept of information richness and human factors are provided to illustrate why VTC can be a valuable decision support system during critical situations involving afloat units.

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I. INTRODUCTION

A. BACKGROUND

Videoteleconferencing (VTC) is a communications method for holding conferences or face-to-face meetings between physically separated geographical locations. Videoteleconferencing incorporates video information, computers, and telecommunication system technologies, a combination which has been termed digital fusion by members of the industry.

VTC systems have a history of requiring extensive investments to implement and operate within an organization. However, with advances in Very Large Scale Integrated (VLSI) circuits, the costs associated with their use have decreased significantly. Private industry has invested in videoteleconferencing as a cost effective measure reducing travel costs and increasing individual productivity. The Department of Defense (DOD), recognizing the advantages of videoteleconferencing, has established its own network, the Defense Commercial Telecommunications Network (DCTN), to accommodate all its requirements through the middle 1990's.

The key issue in selecting videoteleconferencing, and any telecommunications system in general, is to meet the needs of the users. Within this requirement, there are five related issues that must be considered. The first issue involves sophistication. VTC systems range from expensive studio versions with graphics

and facsimile capability to a simple desktop version using a personal computer (PC) as an interface.

The second item of concern is the selection of an adequate data transmission rate to satisfy the human factor. Data rates range from full motion broadcast quality down to freeze frame display only. Since the general population is so familiar with the quality of broadcast television, the use of slower data rates to transmit information may not be acceptable to the user. Therefore, a compromise may be required to ensure implementation of a cost effective system.

Thirdly, there is the selection of the proper data transmission medium. The choices include fiber optic cable, satellite, T-1 digital lines, and the Integrated Services Digital Network (ISDN). Each medium has its own limitations in available bandwidth and associated costs. For example, fiber optic cable has significantly greater bandwidth than does T-1. However, it is more costly. When distance between individual sites is extreme, satellite relay may be the medium of choice.

The fourth issue of concern is cost effectiveness of the system. Each element of a VTC system has associated costs for hardware, software, and facilities. Likewise, VTC systems bring cost savings and unquantifiable benefits when used to their fullest capability. To justify VTC, the user must ascertain that a system will improve operations and prove cost effective in terms of productivity in the long term.

The final issue, and probably one of the most important for the future of VTC systems, is that of interoperability. Since the VTC industry is relatively new, there have been numerous manufacturers establishing their markets with little regard for standardization. Only recently have efforts been undertaken to establish an internationally agreed upon algorithm for compressing bit streams of data required for efficient use of transmission media. Without this standardization, inter-organizational videoteleconferencing would not be possible. If the user's needs require multi-organizational communications, then provisions must be made for using gateways or protocol converters to access various network architectures.

Military commanders possess requirements for timely and accurate communication to ensure proper command and control of their assigned forces. VTC systems have shown the potential for fulfilling this requirement. However, fielding the systems aboard afloat units may require significant tradeoffs in terms of equipment usage and communications circuit allocations. Only through an analysis of user needs, level of sophistication required, available data transmission medium and transmission rate, interoperability, and cost effectiveness can a decision be made to implement VTC in a given environment.

B. OBJECTIVE

The objective of the thesis is to evaluate the technical feasibility of implementing VTC systems aboard afloat naval units. The evaluation involves a

study of possible military applications of VTC, current and projected VTC capabilities within the Department of Defense, pertinent technical issues, and, finally, whether the system would improve communications between individual commands within the chain of command.

C. SCOPE AND LIMITATIONS

The thesis concentrates on the communicator afloat and his requirement for fast and accurate communications through his operational and administrative chain of command. Therefore, only available shipboard communications equipment and data transmission media will be discussed for use in conjunction with VTC hardware. Information on networking possibilities will also be discussed to indicate ship-to-shore paths.

The primary limitation to research of this nature is the lack of specific information on the use of VTC systems within the military. VTC is a relatively new technology and only recently has the DOD realized its potential. Specific DOD regulations and restrictions on using VTC are just now being published. The problems involve determining what information from the private sector can be applied to the military, and whether existing communications equipment can meet the demands of integrating voice and video data on available communications channels.

D. ORGANIZATION

The first chapter provides background about the relevant issues routinely discussed about VTC systems and how they relate to a decision on implementation. The second chapter discusses the technical issues, including hardware such as cameras, encoders/decoders (codecs), and satellites. Chapter three discusses current and projected DOD VTC capabilities with the DCTN and whether this network can satisfy the needs of all potential users. Chapter four provides a description of a system suitable for the shipboard environment. Chapter five discusses information richness with VTC systems and other human factors to consider. The final chapter summarizes the report, provides conclusions reached by the author, and recommends what direction further research should go.

II. VIDEOTELECONFERENCING SYSTEM DESCRIPTION

This chapter provides an overview of the video, audio, graphics, and codec equipment associated with videoteleconferencing (VTC). Satellite transmission channels are discussed exclusive of other media, since they provide the only means available to the afloat user for high speed data transfer during underway operations. The chapter concludes with an evaluation of civilian and military satellites and their compatibility with afloat VTC requirements using existing video, audio, and codec technology.

A. VIDEO, AUDIO, AND GRAPHICS COMPONENTS

The video, audio, and graphics subsystems provide the conversion of images and speech to an analog signal format that can be digitized and transmitted to its destination via existing transmission paths. These subsystems must provide acceptable reception quality at the destination site with a minimum number of required data bits. Keeping the number of data bits to a minimum is essential for cost effective VTC.

1. Video Components and Limitations

Videoteleconferencing employs interactive video which allows individuals at each station to actively participate in a conference. The video components,

cameras and monitors, provide this capability using standards established by the National Television Standards Committee (NTSC), which requires the use of 525 scan lines. The 525 scan lines are divided in half and interlaced together to prevent a flickering effect. Acceptable picture resolution requires a minimum of 483 scan lines which equates to 4.2 Megahertz (Mhz) of bandwidth [Ref. 1:p. 360]. When color information is transmitted, the color and brightness information are combined into a composite signal for transmission.

NTSC monitors are designed with an aspect ratio of 4:3, which means that a 25 inch diagonal monitor is twenty inches high and fifteen inches wide. If a NTSC video signal is digitized to maintain full broadcast capability with these monitors, then it would require a data rate of 80 to 100 megabits per second (MBPS). For this reason, codecs are employed to maximize efficiency of transmitting VTC data. [Ref. 1:p. 360]

The video camera's primary limitation is the amount of noise generated by the conversion of an image into an analog signal. Relatively inexpensive cameras do not have state-of-the-art filtering capability to keep unwanted signals from getting to the transmission path. As a result, the number of data bits required for transmitting a picture increases. This increase in data rate is difficult to accommodate when the available transmission bandwidth is restricted. A more sophisticated camera will keep the bit rate to a minimum by eliminating the noise and provide better picture resolution at the receiving site.

2. Audio Components and Limitations

Minimum acceptable audio input quality for VTC is 300-3200 Hertz (Hz), the bandwidth for the common telephone line. The audio analog signal is converted to digital within the codec at various data rates. Sixty-four kilobits per second (KBPS) is the preferred rate, but this data rate may also be reduced to 32 KBPS and lower, depending upon the codec's capability.

The audio component is faced with echo or feedback problems that could significantly degrade the effectiveness of a videoteleconference. Feedback occurs when a sound from the originating site is picked up by microphones, transmitted to a receiving site and looped back to the original site at a higher volume. This feedback is similar to that experienced when someone speaks into a microphone in a large auditorium and a loud squeal is heard. Feedback can be reduced by using gain switching, which reduces the local volume automatically when someone is speaking. The drawback is that it cuts off any speech received from a remote site. [Ref. 1: p. 355]

Videoteleconferencing systems are also designed to eliminate echoes by storing the transmitted speech in memory and subtracting it from the returning echo before it can be heard by participants. This results in a phase cancellation, which is difficult to achieve. [Ref. 1:p. 355]

Studies in the use of VTC for conducting meetings indicate that degradations in the audio subsystems lead to fatigue in conference participants

[Ref. 1:p. 355]. Therefore, the elimination of the echo and feedback problems significantly improve the effectiveness of VTC as a means of communication.

3. Graphics Components

The graphics component provides hard copy information that may be required during a conference. The installed graphics subsystem may include facsimile, television graphics, high resolution graphics, or personal computer graphics. Facsimile graphics are not widely used in a conference environment due to the excessive time required for transmission. This interruption has a detrimental effect on the flow of the meeting. Additionally, the receiving station must convert the received paper copy into a viewgraph slide prior to presentation to all participants. Also, no cursor or pointer feature is available with facsimile. [Ref. 1:p. 366]

Television graphics is the second method and most widely used. Similar to an overhead transparency machine, it employs an overhead camera above a table with a light source underneath. The camera sends the image to the codec where it is captured as a still frame. There is a short term disruption in the full motion video signal, approximately two seconds at a data rate of 56 KBPS, when transmitting the graphics. Once the graphics have been transmitted, they can be displayed on a screen at the receiving site with a cursor provided by the codec. [Ref. 1:p. 366]

Television graphics always use 480 scan lines which proves inadequate for reading entire typed pages of text. Usually, only one-half page can be read. However, the advantages include color capability, zooming and pointing, and the ability to image three dimensional objects and 35 millimeter slides. The disadvantages include the relatively low resolution previously mentioned and the limitations on screen size due to the low resolution problem. [Ref. 1:p. 367]

The remaining two methods, high resolution and personal computer graphics, involve relatively new technologies and are discussed briefly. High resolution graphics provide the capability to read a full page of typed text and uses facsimile transmission methods. They are relatively costly to use. The use of computers for graphics has been on the increase, and is employed with studio and smaller personal computer sized or desktop versions of VTC. The drawback is that the computers must be compatible at each site to facilitate the graphics data exchange. [Ref. 1:p. 369]

All VTC systems provide graphics capability to enhance the understanding of presented material between two or more distant sites. The method selected is determined by the equipment costs and the requirements for picture resolution. As a general rule, the high resolution graphics are the most capable and costly. Currently, television graphics provide an acceptable compromise in most applications.

B. CODECS

Advances in Very Large Scale Integrated (VLSI) memory chip technology have led to the development of complex encoder/decoders (codecs) that are essential to the cost effective operation of videoteleconferencing systems. Ironically, it is the codec that has hindered the growth of VTC because it uses a sophisticated algorithm to perform data compression. The algorithm is proprietary in nature; therefore, VTC codec manufacturers are unwilling to reveal them and possibly lose their share of the market. This leads to extensive interoperability problems when inter-organizational communications is required between two firms with different codecs. This section discusses the purpose of the codec, video compression techniques, bit rate and error rates, double hop performance, and overall codec performance.

1. The Purpose of Codecs

The codec is responsible for combining audio, video (including control signals), and graphics information; and for compressing the data into a rate suitable for cost effective use of existing transmission medium [Ref. 1:p. 369]. The most common transmission medium used for VTC today is the T-1 digital line with a capacity of 1.544 MBPS. Without data compression, the T-1 digital line could not be used because the data rate required for an uncompressed commercial broadcast television quality varies between 40-45 MBPS

[Ref. 2:p. 3-10]. This data rate far exceeds T-1 capability, and even makes the use of satellites uneconomical for videoteleconferencing.

2. Video Compression Techniques

The data compression methods developed during the past ten years have made VTC achievable over a wide variety of transmission media. Data compression is based on eliminating unnecessary data from a digitized video signal prior to its transmission. This data redundancy elimination forms the basis for reduced bit rates provided by the codec. This section describes data redundancy elimination and various compression methods in use today.

a. Data Redundancy Elimination Theory

Codecs employ redundancy elimination theory for deleting data that is not required for transmission. The two primary theories involve statistical and perpetual redundancy. Statistical redundancy results from a high degree of similarity between adjacent pixels. A pixel is defined as any of the thousands of tiny dots that make up an image produced by a television camera. In other words, pixels in a certain image are not significantly different than others in close proximity. Therefore, every pixel is not required to produce an acceptable image. The second redundancy, perpetual, relies upon the sensitivity of the human eye. The human eye actually blends the pixels into one distinct image on the television screen. For example, any insignificant movement in a person's hand may not trigger enough change in the image to warrant data transmission [Ref. 3:pp. 2-3].

Even with the eliminated data, the transmitted image will still provide acceptable resolution for the viewer.

b. Data Compression Methods

Codecs are designed to follow algorithms using either Differential Pulse Code Modulation (DPCM), Transform Coding, or hybrid coding techniques for compressing data. Early codecs used the DPCM technique which exhibited good performance at higher bit rates. The analog video signals are converted to digital form with DPCM and stored as color and brightness information for each pixel. The pixel information, stored in a memory buffer, is compared with the current picture, and only the differences are transmitted. This results in the desired data compression. However, a problem with the DPCM technique is that moving objects have a jerky motion when viewed at the receiving site. A motion compensation technique is provided to smooth over the movement side effects. Essentially, the movement detector component determines the direction and the amount by which each small area of the picture is moving and predicts the probable position for inclusion in the next transmission. [Ref. 1:pp. 370-371]

The Transform Coding technique is significantly more sophisticated and powerful than DPCM and is performed in two stages. It performs better at lower bit rates but requires more hardware [Ref. 1:pp. 369-370]. With transform coding, the input video image is first divided into numerous sub-pictures that are compressed individually. The transform coding process involves the assignment

of up to 16 digital values for the color and brightness information in each scan line within these sub-pictures. The greater the number of digital values for a sub-picture transmitted, the better the picture resolution. In fact, if all 16 values are transmitted, the original line is reconstructed. [Ref. 1:p. 371]

The second step in transform coding is to individually encode each digital value for transmission. This is accomplished by prioritizing the values obtained for the color and brightness information in each sub-picture. The values with the highest priority represent pixels in the upper left corner of each sub-picture and are transmitted first. The remaining values are sent only if transmission time allows. This results in the video data compression. In most video images, many of the digital values within a sub-picture do not change often enough to require continuous transmission. Their absence in a transmitted signal has little impact on the received picture resolution. [Ref. 2:pp. 3-12,13]

The more sophisticated the method, the greater the compression ratio and the lower the bit rates. Overall, Transform methods are more sophisticated and superior to DPCM in their ability to provide lower bit rates and suffer from transmission errors with minimum image quality degradation. This is because each error in transmission is isolated to a single sub-picture. Therefore, errors distributed over a large number of sub-pictures would be nearly indiscernible. For a strictly DPCM technique, however, errors are not isolated to

one block and may occur on one or more scan lines. The result may involve noticeable streaking of the image at the reception site. [Ref. 4:p. 5]

Hybrid codecs combine the best features of DPCM and Transform coding techniques. The Compression Labs Inc. (CLI) Rembrandt codec, for example, is a hybrid that uses both transform and DPCM techniques. When DPCM is added to the transform coding process, only the difference between the digital values for color and brightness information during each transmission time is sent. In other words, no data would be transmitted for a stationary image. If movement does occur, a feedback mechanism eliminates the least important terms. As the complexity or movement of an image increases, the amount of data required for representing the image increases also. As a result, the feedback mechanism must eliminate more data for a complex image than it would for a stationary object. This elimination of data has a detrimental effect on received picture resolution. [Ref. 1:pp. 372-373]

3. Codec Bit Rates

The codecs used in broadcast television do not perform any data compression and would not be practical for use in VTC systems. The commercial television industry, for example, uses a codec which operates at 208 MBPS to digitally store very high quality television images for intra-studio application. Approximately 40-45 MBPS is required to digitally transmit an uncompressed television signal while maintaining excellent signal quality. With VTC, however,

a codec must be used for reducing this bit rate down to 1.544 MBPS or lower to make efficient use of the transmission media. The lower the bit rate, the greater the number of conferences that can be accommodated over a given transmission path. A special class of codecs have been used in Command and Control applications to provide high resolution and excellent motion responses. These codecs operate between 22 and 63 MBPS, which requires an extensive amount of bandwidth on a given communications channel, and is still higher than the 1.544 MBPS used with VTC systems. Figure 1 provides a hierarchical chart of full motion video codecs and their associated bit rates. [Ref. 2:pp. 3-8,9,10]

4. Multi-bit Rate Codecs and Their Application to Command and Control Circuits

Multi-bit rate codecs are essential to the reliability of command and control circuits. During emergency conditions, transmission bandwidth may not be available to conduct full motion videoteleconferencing at 1.544 MBPS. Other important circuits may be necessary to monitor the situation, or hostile action may have eliminated overall communications capability. Therefore, the bit rate may necessarily be limited to 64 or 56 KBPS. Once the communications link has been restored to full capacity, the codec can revert back to a higher bit rate [Ref. 3:p. 1].

Transform coding with movement compensation is used in multi-bit rate codecs. This coding method transmits only the changes in an image. As the

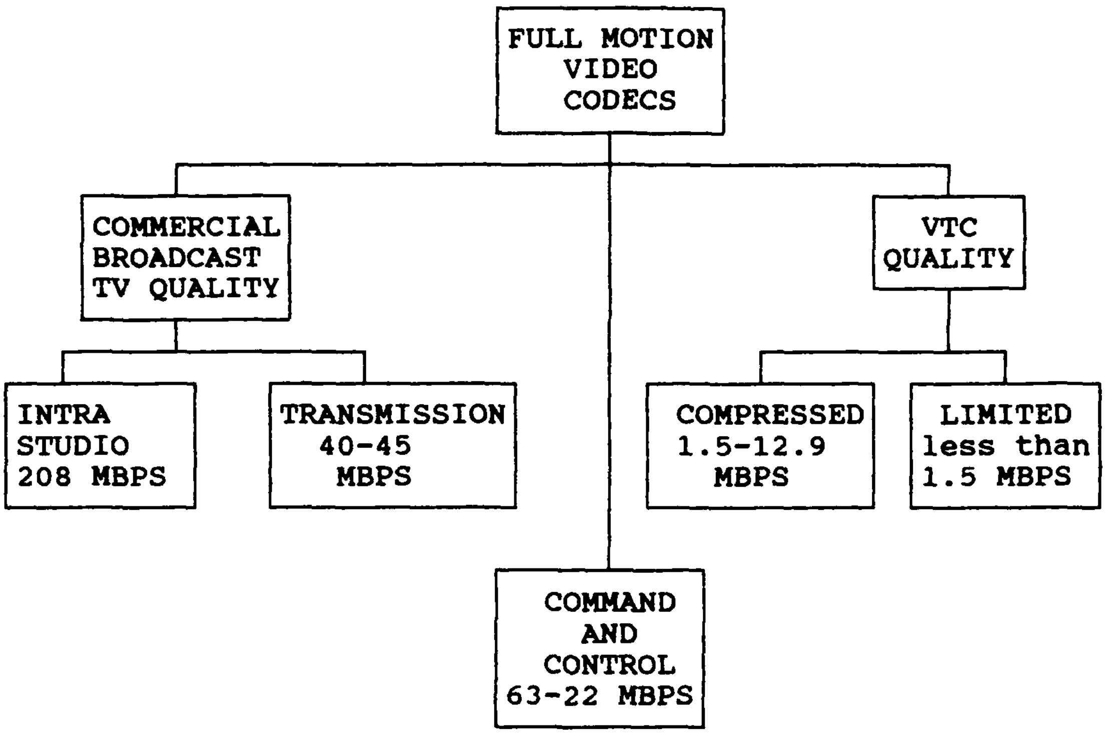

Figure 1. Hierarchy of Bit Rates in Codecs

image becomes more active, the amount of information required for transmission increases. Since the bit rate is established for a particular connection, a buffer memory is used to store the resulting overflow. The codec then alters its parameters to prevent such an overflow from occurring.

This results in signal quality degradation, but is performed in such a way that it is not perceptible to the viewer. When the image slows in activity, the codec reverts back to normal operation. Movement compensation is employed to eliminate the erratic motion of the image, which is particularly important in

low bit rate codecs. This compensation method is effective primarily when the image is limited to the head and shoulders view of one individual. [Ref. 3:p. 7]

An important factor to consider with low bit rate codecs is the amount of noise introduced into the system. The primary source of noise is use of inexpensive color cameras and inadequate lighting. Since little information is transmitted with low bit rates, the amount of noise may be equal to or greater than the information. This results in higher channel bit rates and a degradation in image quality. Special filters are used to reduce the effects of noise prior to transmission. [Ref. 3:p. 16]

A certain number of bits must be reserved for overhead in a digital transmission line. This overhead includes bits for synchronization, framing, and error protection. Overhead ultimately results in a reduction in the number of bits available for coding of video information. Table 1 provides a list of bit rates allocated for video and overhead information. [Ref. 3:pp. 35-36]

TABLE 1. DATA AND OVERHEAD BIT RATES

Available Transmission Bit rate	Video Info Rate	Reserved for Overhead
64 KBPS	50 KBPS	14 KBPS
128 KBPS	100 KBPS	28 KBPS
256 KBPS	200 KBPS	56 KBPS
448 KBPS	375 KBPS	73 KBPS
832 KBPS	750 KBPS	82 KBPS
1.5 MBPS	1.35 MBPS	150 KBPS

As the number of data bits transmitted increase, the number of bits required for synchronization, error correction, and encryption increase as well.

5. Bit Error Performance

Bit error performance is important since the overall performance of the codec and the received picture resolution are affected by the number of data link errors that occur during transmission. These errors may significantly alter the compression algorithm. Higher compression ratios produce lower bit rates which are more susceptible to errors in the compression process. With transform compression, a bit error could affect several pixels for several successive data transmissions.

Codecs can use forward error correction coding that detect and correct data link errors. The decoder compares the received data check bit against the check bit it calculated for the data bit stream. If the received and calculated check bits do not match, the decoder attempts to correct the data bit stream by altering a few bits to make a word fit. This correction is based on a most likely pattern of errors that caused the mismatch. The advantage with forward error correction coding is that the data can be corrected without requiring a retransmission of the data bit stream. However, the tradeoff lies in additional transmission overhead and fewer bits available for transmitting video information. [Ref. 2:p. 5-43]

Decoders at the receiving site are designed to operate with bit error rates as high as one in 10^{-4}, and still maintain frame synchronization. This error rate, if maintained, will result in serious degradations in picture quality. One error in 10^{-5} or 10^{-6} is considered an acceptable rate for long term connections and is often used as the nominal error rate in satellite systems. [Ref. 5:p. VII-A-12]

In addition to forward error correction coding, decoders employ special buffer memories that look ahead in the data bit stream and validate the most important section of the data, which is the signal identifying the start of a new line of video. Buffers are also used to allow the decoder to jump a frame in the event that an error in that frame has occurred which severely degrades frame synchronization. [Ref. 5:p. VII-A-12]

6. Data Encryption

All VTC systems employ data encryption to ensure the privacy and security of their conferences. The digital nature of the codec makes encryption a relatively simple task. All major codec vendors use the Data Encryption Standard (DES) to provide privacy for commercial systems. Most codecs are also compatible with National Security Agency (NSA) approved bulk encryption devices used in military applications. The use of encryption devices also represents a tradeoff in the bit rate. Additional bits are required to encrypt the signals, resulting in fewer bits available for encoding video information.

The encryption device should provide a warning to participants on the security of the circuit. This warning would be a simple message displayed on the monitor with the words "CRYPT" or "NO ENCRYPTION" to provide security status advisories [Ref. 5:p. VII-A-13]. This warning is particularly important in the case of an unforeseen failure of the encryption device.

7. Multipoint Capability with Codecs

Multipoint capability provides the means to link numerous stations together simultaneously. This is important in VTC military applications when the need arises to link more than two command centers together for a conference. Multipoint systems require the switching of video, audio, and control signals between the conference sites. The actual data links established for multipoint conferences are bi-directional which provide a continuous video image of all participants at each conference site. Other options with multipoint systems include voice activated display of the person doing the talking or centralized control of video by a designated conference site. For voice activated and centrally controlled switching systems, a separate channel is required for communications between control unit and codec. [Ref. 5:p. VII-A-13]

In the multipoint system, the decoder receives a warning that a pending video switch is to occur. The decoder then freezes the current image in memory for a very short time until the switch occurs. This process is completed with little degradation in received signal quality [Ref. 5:p. VII-A-13].

Encryption capability is available, but limited, in certain circumstances. Encryption is performed by switching the audio and video together or encrypting the audio separate from the video information. The limitation is the lack of a NSA approved audio switching device or bridge to handle multiple levels of security simultaneously. In other words, a conference could be limited to only one classification level, either confidential, secret, or top secret, and all participating sites must meet the requirements for that particular security level.

8. Double Hop Codec Capability

Codecs have been tested for use in double hop situations where the video signal is transmitted long distances via two satellites. Despite acceptable performance of codecs in maintaining synchronization, degradations in the received signal quality occur as a result of the inherent time delay along lengthy transmission paths [Ref. 6:pp. 4-13,14].

9. Standardization Issues with Codecs

The subject of standardization in codecs is important to the interoperability of VTC between different organizations. Without internationally agreed upon standards for codec data compression techniques, systems designed for one organization or application will not be able to communicate with other VTC systems. Standardization requirements have been discussed in numerous reports and periodicals during the past six years. In 1984, Robert Keiper, then manager of marketing planning at Compression Labs, stated that compatibility

between all codecs would not happen in the near future because there are too many things against it. He went on to say that if codec producers were asked to stop developing their own and sell someone else's codec they would eventually leave the industry [Ref. 7:p. 57]. Keiper's statement appears prophetic since no codec standards exist today. However, the International Consultative Committee on Telegraphy and Telephony (CCITT) is expected to issue a new interoperability standard for codecs operating between 64 KBPS and 2 MBPS by the year 1992 [Ref. 8:p. 7].

The question arises as to whether such a standard will be accepted throughout the industry. John Nuwer, then director of teleconferencing services for Isacomm, stated in 1984 that just because standards are established doesn't mean they have to be followed [Ref. 7:p. 58]. If the same attitude is taken by the industry as a whole, then interoperability problems will continue to exist in the near future.

The most significant parameter requiring standardization is the compression algorithm. A study conducted of major codec vendors revealed that none of the compression algorithms were compatible or interoperable. Although the majority of codecs used a form of transform coding in their algorithms, the additional options for motion compensation widened the interoperability gap [Ref. 2:p. 7-9]. As a result, the outlook for compatible codecs is not good.

Within military circles, the prospective VTC user must ensure that any codec procurement meets the interoperability requirements that exist for a given circuit.

10. Overall Codec Performance

Tests and evaluations on codecs operating at 1.544 MBPS were sponsored by the Defense Advanced Research Project (DARPA) during the mid 1980's. Of the four models tested, Compression Labs Incorporated's model VTS-1.5 E was determined to be the best overall for military applications [Ref. 6:p. 4-8]. Compression Labs Inc. have made significant progress in compression technology. They recently introduced the Rembrandt 56 codec which can compress data down to 56 KBPS. The Rembrandt 56 is ideal for users with limited bandwidth availability who intend to use a desktop version of videoteleconferencing. A second Rembrandt model operates at higher transmission speeds ranging from 384 KBPS to 1.544 MBPS. This model is capable of connecting up to 64 workstations in a local area network [Ref. 9:pp. c\1,c\4]. Rembrandt codecs have been chosen as the interim standard for DOD VTC applications to ensure interoperability between individual users. [Ref. 10:p. 3.6.1].

The Rembrandt codec provides the necessary features of variable bit rate capability and strong performance under varying channel error conditions to support command and control circuit requirements for afloat users. In addition, the Rembrandt codec is currently in use with the DOD's Defense Commercial

Telecommunications Network (DCTN) and provides the added measure of interoperability if and when a ship-shore VTC link is established.

C. SATELLITE SYSTEMS

Satellite communication is essential to the effective command and control of afloat units. Without satellites, the use of VTC or any other high speed data circuits would not be feasible. High frequency (HF) channels are significantly affected by ionospheric conditions and do not provide the required data rate, distance, or reliability that satellites provide. Therefore, the technical feasibility of employing VTC systems aboard afloat units depends upon the use of existing satellites for relaying the data between conference sites. This section provides an overview of satellite transmission characteristics and accessing methods that are employed with VTC systems. This discussion is followed by a description of commonly used military satellite systems and their compatibility with VTC requirements.

1. Satellite Characteristics

Satellites are essentially microwave repeaters in space that provide high capacity data transfer over long distances. They also provide point to point, point to multipoint, and multipoint to multipoint services directly to the user sites. Satellites can accommodate various types of traffic, including voice and data. For videoteleconferencing, the traffic is characterized as a two way, real time, wideband transmission over dedicated private lines or switched via public or

private networks [Ref. 11:p. 12]. Satellites provide exceptionally more channel capacity and better quality and reliability than the traditional long distance high frequency (HF) circuits.

There are limitations and disadvantages with satellite communications systems. Since military satellites are in geosynchronous or geostationary orbits at the equator, their coverage, although global, is limited to the region between 70 degrees north latitude and 70 degrees south latitude [Ref. 1:p. 55]. The lack of polar coverage could be a significant problem for operating forces in these regions. VTC capability would not be available. Secondly, geosynchronous orbits are established at approximately 23,600 miles above the earth's surface. The significant distance the electromagnetic wave must travel via the earth-satellite-earth path causes a delay of approximately 270 milliseconds. This results in an echoing problem for audio transmissions which is overcome with the use of echo cancelers. The delay problem is not noticeable for video transmissions [Ref. 12:p. 53].

Finally, there is the frequency allocation problem. Satellites are limited by the number of transponders or channels installed. Depending on the modulation technique used, a near full motion VTC can require an extensive amount of bandwidth and channel capacity. Therefore, all user requirements must be prioritized to fulfill the most important missions first.

Satellites employ a technique called frequency reuse in which orthogonal polarity allows the same frequency to be used, only ninety degrees offset, without interference [Ref. 11:p. 242]. This use of vertical and horizontal polarity or right hand and left hand circular polarity actually doubles the capacity of the individual transponders.

Multiple access methods are also used to increase the number of users on a particular satellite and will be discussed briefly in later paragraphs. The remaining option to alleviate the frequency allocation problem is to use higher frequency satellites that provide a larger available bandwidth and closer spacing of satellites in orbit. However, the drawback with higher frequencies involves greater signal attenuation from weather, particularly precipitation [Ref. 12:p. 54]. Table 2 provides a listing of the frequencies in use or proposed for satellite communications [Ref. 1:p. 57].

TABLE 2. FREQUENCIES ALLOCATED FOR SATELLITE USAGE

Band	Downlink Bands	Uplink Bands
Uhf-Military	225-328.6 Mhz	335.4-399.9 Mhz
C Band-Commercial	3.7-4.2 Ghz	5.925-6.425 Ghz
X Band-Military	7.25-7.75 Ghz	7.9-8.4 Ghz
Ku Band-Commercial	11.7 -12.2 Ghz	14-14.5 Ghz
Ka Band-Commercial	17.7-21.2 Ghz	27.5-30 Ghz
Ka Band-Military	20.2-21.2 Ghz	43.5-45.5 Ghz

2. Multiple Access Methods

Digital signaling methods require a greater bandwidth but they can withstand relatively poor signal to noise ratios. Multiple accessing methods such as Frequency Division Multiple Access (FDMA), Time Division Multiple Access (TDMA), and Demand Assigned Multiple Access (DAMA) are used to alleviate the large bandwidth requirement. FDMA designates a particular signal to one of many frequencies assigned to a satellite channel, whereas TDMA assigns a particular time for each site to transmit on a particular frequency. [Ref. 13:p. 311]

An exclusive carrier frequency and bandwidth on a transponder is assigned to a specific earth station with FDMA. Bandwidth is allocated based on the required traffic capacity. Guardbands are used to separate assigned frequencies on a transponder to eliminate any overlap and interference problems.

FDMA has been the most widely used access method over the past 20 years, and will continue to carry analog trunk telephone and broadcast television service in the future[Ref. 13:pp. 320-321]. FDMA is characterized by simplicity in earth station equipment, but is limited in the number of channels transmitted. This multichannel limitation requires each earth station to control uplink power to avoid intermodulation problems, and complex frequency plans with unique assignments and traffic capabilities [Ref. 11:p. 402].

Each earth station accessing a satellite with TDMA occupies its own time slot which it uses to transmit a short burst of compressed data on an

assigned carrier frequency [Ref. 13:p. 321]. One carrier frequency is assigned to a transponder. Burst duration depends on traffic requirements. The more traffic to send, the longer the burst duration. As soon as a station completes its transmission, another station transmits during its assigned time slot.

TDMA is strictly digital, uses maximum power capability of a transponder, and makes maximum use of available bandwidth. However, earth stations are significantly more complex and costly than those employing FDMA because of the network timing requirements and high data burst rates of 60-120 MBPS [Ref. 11:p. 403]. TDMA use in military satellites is essential because of unequal transponder bandwidths, ranging from a few megahertz in the case of ultra high frequency (UHF) satellites and 185 MHZ in super high frequency (SHF) band satellites [Ref. 14:p. 2-27].

Demand Assigned Multiple Access (DAMA) is a complex version of TDMA where a station transmits during time allocations that are based on traffic load at a particular instant [Ref. 1:p. 74]. The station has no preassigned time, frequency, or space slot for transmission. Rather, a channel request results in a temporary assignment to permit one or two-way service [Ref. 11:p. 402]. DAMA is used extensively in UHF military satellites to make efficient use of available bandwidth.

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[Ref. 15:p. 5.7]. These satellites are equipped with 24 transponders and approximately 500 Mhz of total bandwidth available. Each transponder possesses a 22 Mhz passband which is separated from adjacent transponders by a six Mhz guardband to eliminate intermodulation problems. Capabilities include 1200 analog voice channels and usually one or more channels for broadcast television [Ref. 16:p. 156]. Examples of C band satellites include Spacenet-4/GSTAR-3 owned by GTE Spacenet, the Telstar constellation which is owned and operated by the American Telephone and Telegraph Company (AT&T), and the Maritime/International Maritime Satellites (MARISAT/INMARISAT).

The MARISAT/INMARISAT satellites are allocated specifically for the shipping industry and have been operated at bit rates up to 9600 BPS. Transmission rates have gone as high as 56 KBPS with modifications to the earth terminals. The primary data transmitted is in the form of hard copy telex. An INMARSAT consortium is responsible for channel allocations. [Ref. 17:p. F.3.1.1] All of the aforementioned satellites are used within military circles.

Ku band satellites have been used since the mid 1970's. They provide extensively greater bandwidth than C band satellites, and possess transponders as wide as 50, 72, and 240 Mhz. They can provide up to 86,400 two-way voice channels and broadcast television capability [Ref. 16:p. 156]. The problem with Ku band satellites is that they are susceptible to severe propagation losses during periods of precipitation at the earth stations. However, their use has

resulted in the growth of Very Small Aperture Terminals (VSAT) and an increase in the number of firms using videoteleconferencing. Examples of Ku band satellites include the ASC constellation owned by American Satellite Corporation and the SBS constellation owned by Satellite Business Systems [Ref. 15:p. 6.4].

b. The FLTSATCOM System

The FLTSATCOM System provides multichannel communications for U.S. Navy mobile units and shore facilities. It consists of a four satellite constellation providing global coverage from orbits located above the Indian, Atlantic, and Pacific Oceans. Each satellite possesses 23 channels in the 244 Mhz to 400 Mhz (UHF) range with nine 25 Khz wide channels designated for Navy use and twelve 25 Khz wide channels for Air Force use. One 25 Khz wide channel is reserved for the Fleet Broadcast, which provides one way record communications from shore facilities to afloat units. This involves a SHF uplink to the satellite and a UHF downlink. Additionally, the FLTSATCOM satellites have one 500 Khz wideband channel designated for use by the National Command Authorities (NCA) [Ref. 18:p. 377]. Three frequency plans are used to prevent radio frequency interference and allow more than one satellite to operate in the same area [Ref. 14:p. 6-109]. The total useable bandwidth on FLTSATCOM is 810 Khz [Ref. 14:p. A-44].

LEASAT's capabilities include seven 25 Khz channels, five-five Khz channels and one 500 Khz wideband channel [Ref. 19:p. 72].

Ultra high frequency satellites such as the FLTSATCOM and LEASAT are ideal for small mobile units because they allow broader beamwidths to ease the antenna pointing and tracking requirements [Ref. 14:p. 2-10]. This feature is essential to maintaining satellite track in higher sea states. The disadvantage is that there is a limited radio frequency spectrum available to the users. Special multiple access techniques, primarily DAMA, are used to improve the capabilities of the satellites to support a wider variety of communication circuit requirements.

The FLTSATCOM System is controlled by earth terminals located at the four Naval Communications Area Master Stations (NAVCAMS). These NAVCAMS are located in Hawaii, Guam, Italy and Norfolk, VA. The Naval Communications Station, Stockton, California has the capability to control the FLTSATCOM system and acts as a backup for the NAVCAMS. Each NAVCAMS falls under the operational control of the Commander-in-Chief (CINC) of fleet units in a particular area of responsibility, who sets priorities on communications circuits for use with FLTSATCOM.

Afloat terminals for the FLTSATCOM system consist of multiplexers, modems, analog to digital converters, cryptographic equipment, and the WSC-3 UHF transceiver. The WSC-3 transceiver has a frequency range of 225-399.975 Mhz and transmits in the Frequency Modulation/Amplitude Modulation (wide or narrow band), frequency shift keying (FSK), or phase shift

keying (PSK) modes. It has internal modulation and detection capability at 75 BPS FSK and 75 BPS to 9.6 KBPS with PSK modulation. Higher data rates are available with programmable modems [Ref. 18:p. 371]. Cryptographic equipment is limited to the KG-36 which provides half duplex encryption of digital data.

FLTSATCOM is a Navy run program specifically allocated to servicing afloat users. Its capabilities are limited by the available bandwidth for higher data rate applications such as VTC. However, the Defense Satellite Communications Satellite system provides significantly more bandwidth and may be compatible with VTC requirements.

c. The Defense Satellite Communications System (DSCS)

DSCS was implemented in three phases to provide SHF communications for DOD users. The Defense Communications Agency is responsible for controlling user access and developing frequency plans [Ref. 14:p. 5-18]. Specific services include the following:

1. Support Presidential communications and the World Wide Military Command and Control System (WWMCCS) by providing communications services between the National Command Authorities, Defense Communications Agency and unified/specified commands, between the unified/specified commands and general war combat forces, and communications from early warning and intelligence sites.

2. Provide high capacity, reliable, independent communications capability in support of contingency and limited war operations and to restore primary Defense Communications System (DCS) transmission subsystems that may become inoperative due to natural causes or direct enemy action.

3. Augment DCS with a transmission subsystem capable of providing wideband channels required to handle high quality secure voice, high speed data between automated command and control centers, high resolution graphics and imagery, and rapid transmission of sensor data.
4. Provide DCS service to remote locations not adequately served by other means.
5. Support Navy ship-to-shore communications and other authorized users.

[Ref. 18:p. 373]

The services that the DSCS is designed to support fall within the scope of VTC. First, VTC systems are employed in existing command and control and intelligence circuits. Secondly, DSCS provides the necessary wideband channels for supporting high speed data required in VTC applications. Thirdly, the DSCS is designed to support Navy ship-to-shore communication requirements. Therefore, the use of DSCS for afloat VTC connectivity would not conflict with the services this satellite program is designed to provide.

The DSCS III program provides the greatest capability of the three phases and will be discussed in detail. The first satellite was launched in 1982 with fourteen additional launches planned through the middle 1990's. DSCS III provides long haul voice, data, and facsimile transmissions in a high level jamming environment. The system must accommodate a wide variety of earth terminals ranging from 30 inches to 60 feet in diameter and a wide range of data bit rates from teletype up to 20 MBPS. [Ref. 14:p. 6-84]

The DSCS III system is composed of four satellites in geosynchronous orbit. Each satellite consists of six independent transponders and a number of up and downlink antennas. Each transponder operates in the SHF band, specifically 7.9-8.4 Ghz uplink and 7.25-7.75 Ghz downlink. Any type of modulation or multiple access technique can be used [Ref. 14:p. 6-91]. Total usable bandwidth of these satellites is 500 Mhz with a communications capacity of 1300 duplex voice channels or up to 100 MBPS of data [Ref. 14:p. A-43]. DSCS III control stations are often co-located with FLTSATCOM terminals at the various NAVCAMS around the world.

The DSCS III system terminals for afloat units usually consists of the WSC-6 SHF transceiver, time division multiplexing equipment, analog to digital converters, phase shift keying modems, codecs, and cryptographic equipment. The WSC-6 was developed for use in the 1990's as the Navy's command and control system providing secure global connectivity for voice and data transmissions. It includes a single or dual inertially stabilized antenna system able to maintain track on the satellite in up to sea state five. Inertially stabilized antennas are essential in the SHF band because the beamwidth is significantly more narrow than beamwidths associated with UHF systems. The WSC-6 is currently aboard U.S. Fleet command ships providing ship-to-ship and ship-to-shore connectivity [Ref. 18:p. 372]. The WSC-6 is also compatible with the North

Atlantic Treaty Organization (NATO) satellites, Skynet, and future SHF satellites [Ref. 14:p. 5-59].

Important ancillary equipment include the KY-801 (B) Codec and the KG-81. The KY-801 (B) is a Forward Error Correcting (FEC) codec capable of operating up to ten MBPS with a variety of PSK modems. It processes the applied bit stream at one and a half times the rate of the original digital bit stream [Ref. 20:p. 13-3]. Encryption is provided by the KG-81 full duplex key generator capable of operating at bit rates between 9.6 KBPS and 20 MBPS [Ref. 20:p. 6-58].

Satellites provide the capability to reliably communicate with one or more locations over long distances. These individual locations become part of a network which is controlled and operated as a single unit. The various networking schemes are explained in the following section.

D. SATELLITE NETWORKS

Satellite networks are classified as either point to point, point to multipoint, or multipoint to multipoint connections. With a point to point network, the circuit remains intact throughout the duration of the call. For this reason, point to point networks are often called a "cable in the sky" [Ref. 11:p. 86]. The connection can be dedicated for full-time use or patched when required. Figure 2 details a satellite point to point network between an afloat unit and a fleet commander-in-chief (CINC). Communications along this network could be full duplex,

meaning simultaneous two-way communications, or half duplex, meaning alternating one way communications between stations. A modification to the point to point methods adds a switching device which allows three or more stations to confer with any one of the other stations at given time [Ref. 2:p. 6-4].

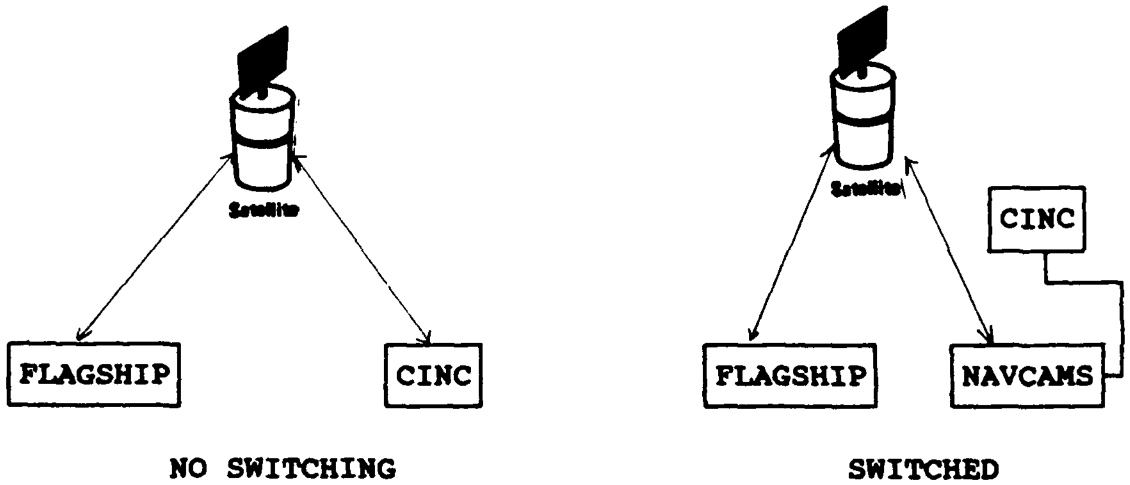


Figure 2. Point to Point Connection

Point to multipoint connections take full advantage of the satellite's broadcast capabilities. Figure 3 represents a point to multipoint broadcast between a NAVCAMS and afloat units for the purpose of transmitting a simplex or strictly one way fleet broadcast. Each afloat unit is responsible for sorting the incoming data by employing FDMA/TDMA techniques [Ref. 11:p. 88]. With multipoint connections for video and audio communications, video is normally provided continuously for each participant or switched by voice activated cameras;

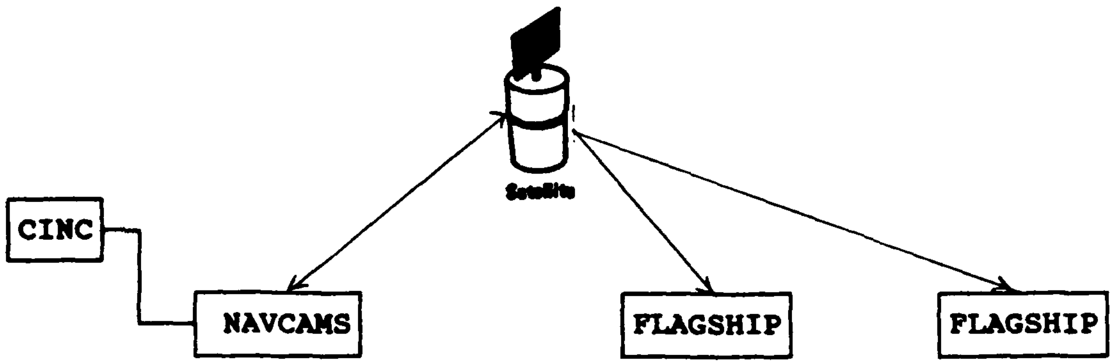


Figure 3. Point to Multipoint Connection

whereas audio is provided through an audio bridge at a central switching facility [Ref. 21:p. 19.3.1]. This particular method for switching is called distributed and is well suited for multipoint videoteleconferencing [Ref. 21:p. 19.3.2].

Multipoint to multipoint connections are the most complex. These connections are characterized by one station transmitting and receiving a videoteleconference from one or more stations simultaneously. These connections are dedicated or switched and require two or more communication links. Figure 4 depicts a multipoint to multipoint configuration. [Ref. 2:p. 6-4]

Private networks provide direct access of the users to the network and can be compared to either FLTSATCOM, LEASAT, or DSCS III systems for the DOD. Military units are not required to request use of the net from a commercial carrier prior to gaining access. This access is normally handled by the NAVCAMS. Additionally, earth stations may be located at major command

centers, forming another private network, and bypassing other local facilities such as a NAVCAMS.

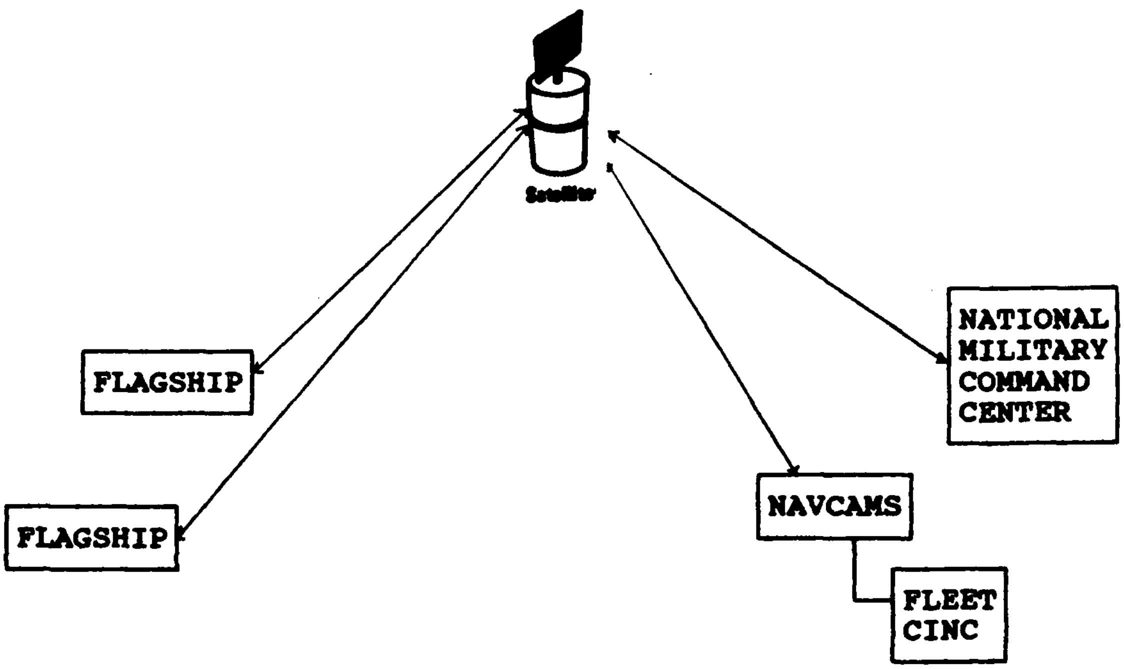


Figure 4. Multipoint to Multipoint Connection

E. VIDEOTELECONFERENCING WITH SATELLITES

Commercial satellites are designed to accommodate the video requirements of VTC. Telstar 3, a commercial satellite operated by AT&T, has the capability to relay 360 simultaneous videoteleconferences [Ref. 22:p. 35]. However, military satellite systems were not designed with video as a major concern, particularly

with FLTSATCOM. As a result, certain tradeoffs or equipment modifications are necessary to support any VTC requirements for afloat units.

First, the use of multiple accessing techniques such as TDMA and DAMA is essential to the maximization of satellite transponders. TDMA ensures that other important circuits can be maintained with the remaining available bandwidth. DAMA is particularly important because demands for video transmission only arise periodically, and it would be inefficient to reserve a significant amount of bandwidth on a continuous basis. Therefore, the VTC system should be compatible with existing DAMA capability. However, this DAMA feature will not ensure immediate access or reaction on demand. A booking system is maintained for most commercial VTC satellite applications to meet the needs of all users. Participants must reserve satellite time prior to scheduling a conference. This may suffice for long term planning, but is unacceptable for a command and control network where speed and reliability of the communication channel is essential. Consequently, DAMA may be required to transmit a continuous synchronization signal for maintaining access to the designated communications channel. [Ref. 23:pp. V-A-1,3,4]

Secondly, the FLTSATCOM system has a limited amount of bandwidth available to support all communications requirements for afloat users. Even with multiple accessing methods employed, the 25 KHZ wide transponders could not support near full motion video. Assuming a binary PSK modulation, the maximum

bit rate for the transponder is 50 KBPS. Therefore, these transponders are limited to freeze frame or slow scan video that can be transmitted as low as 1200 BPS, which is essentially the equivalent of a standard voice channel [Ref. 16:p. 84]. However, this data rate is normally unacceptable for any circuit requiring extensive interaction among participants. Near full motion video may be transmitted as low as 384 KBPS, but the tradeoff is twelve 32 KBPS voice channels. In this case, facsimile may provide the same amount of information at a lower cost.

The alternative with the narrowband FLTSATCOM transponders is to use a more sophisticated modulation technique called Quadriphase Shift Keying (QPSK). This technique increases the narrowband transponder channel capacity up to 100 KBPS and permits limited motion VTC at 56 or 64 KBPS.

The other option with FLTSATCOM is to use a portion of the wideband 500 KHZ transponder for VTC transmission. This transponder provides an adequate bandwidth of one MBPS for near full motion video, assuming binary PSK modulation and two MBPS with QPSK. However, the tradeoff, as in the case of the 25 KHZ transponders, is deleting some of the other circuits on the transponder to accommodate VTC. The circuits allocated on the wideband transponder are currently reserved for the National Command Authorities' use and would have to be reallocated on a priority basis to Navy subscribers. Overall,

the use of FLTSATCOM and its limited bandwidth is not the optimum carrier for VTC in afloat users.

The DSCS III satellites provide greater bandwidth flexibility since they operate in the SHF band. The tradeoffs in bandwidth and circuit allocation continue to exist, but accommodating VTC would not have as much impact as it would with FLTSATCOM. The drawback is that only fleet command ships have or are expected to have the necessary terminal equipment to access the DSCS III satellites. This effectively eliminates all afloat units from VTC capability who have FLTSATCOM access only. Various proposals have been submitted to provide SHF capability to these units that would provide them access to the DSCS III satellites. One proposal would install low cost SHF communications terminals aboard mobile units. It would provide a single channel tactical terminal operating in the DSCS III band of 7-8 GHZ. This installation would require a "hub-and-spoke" arrangement with a large earth station similar to a NAVCAMS at the hub to accommodate the smaller shipboard terminals. [Ref. 24:p. 11.6.1]

Another proposal involves providing the DSCS III satellite with a frequency extension so that they may operate in the Ku band and be compatible with commercial satellites in that range. The uplink frequency would increase from 7.9 to 14.9 GHZ and the downlink frequency would increase from 7.25-7.75 GHZ to 12.0-13.0 GHZ. This would increase the total available bandwidth by 7 GHZ and allow DSCS III to access commercial satellites that routinely provide VTC

services. The frequency extension to the Ku band is preferable to the C band because C band is already heavily allocated. The drawback for afloat users is that Ku band represents even smaller beamwidths which would result in significant satellite tracking problems in heavier sea states. [Ref. 25:p. 20.5.2]

Finally, the satellite networks must be compatible to transfer VTC data from the afloat user to the command center or any other designated terminal. For a point-to-point connection, switching may not be a significant problem. An earth terminal located at the command center would permit direct access for the afloat user, similar to a private network setup. If the earth terminal is not located at the destination station, the data must be switched through an earth station similar to NAVCAMS to its destination via compatible digital lines like the T-1 digital line. Point to multipoint transmission similar to a Fleet Commander holding a VTC with afloat flagships takes full advantage of the satellite's broadcast capability and would not pose a significant problem. Multipoint to multipoint connections, however, present extensive switching problems and would require a lead time to establish each of the connections.

F. CHAPTER CONCLUSION

The use of VTC systems aboard afloat units is technically feasible with existing satellite systems. This depends upon attaining low enough data rates to permit simultaneous use of VTC with other high priority communications circuits. Variable bit rate codecs are essential because data rate can be adjusted lower

when channel capacity is reduced and increased when channel capacity is restored. Codecs also provide acceptable bit error rates and encryption capability to support military satellite system requirements. The important issue with codecs is that their compression techniques must be compatible at both terminals.

Military satellites do provide acceptable bandwidth for near full motion VTC whether it is the wideband transponder in FLTSATCOM or the individual transponders on DSCS III satellites. However, the tradeoffs in the number of circuits that must be brought down to support VTC must be considered. For this reason, DSCS III may be the best alternative because of its greater bandwidth capability. However, the use of DSCS III reduces the number of afloat units that presently have a VTC capability. Even with the satellite's compatibility with VTC, the networking must be in place to support end-to-end connections. Point-to-point connections, such as a Fleet Commander to afloat flagships, are the easiest to accomplish because of the limited switching requirements.

The next chapter focuses on videoteleconferencing systems in place, or planned within the military, and evaluates whether these systems are compatible with a videoteleconferencing system for afloat users.

III. DEFENSE USE OF VIDEO TELECONFERENCING SYSTEMS

This chapter provides an overview of the Department of Defense (DOD) VTC organization and the policy regarding new system acquisitions and interoperability. A discussion on various VTC networks is included to illustrate what VTC capabilities exist today and what is envisioned for the future. The chapter concludes with an evaluation of current and planned VTC networks and whether they would be compatible with afloat VTC system connectivity requirements.

A. BACKGROUND AND DOD ORGANIZATION

Historically, VTC use in the DOD has centered on individual commands who have identified a requirement, conducted the required cost effective analysis, and procured a system to support their own objectives. This process has resulted in myriad VTC systems that are not interoperable and exhibit a great deal of redundancy between them. The growing demand for VTC in all levels of military applications has brought to the forefront a need for establishing standards that will ensure connectivity of VTC systems in the future.

The Assistant Secretary of Defense (ASD) for Command, Control Communications and Intelligence (C3I) is the governing authority for DOD VTC systems. ASD (C3I) is responsible for providing policy guidance and

managerial oversight of all Defense Department VTC applications. [Ref. 26:p. 3] The overall DOD policy states that all VTC programs must meet the interface criteria necessary for the connectivity between systems and networks implemented by different contractors. The specific objective of this policy is to ensure that all systems are fully interoperable and support an environment that enhances productivity, efficiency, and accomplishment of operational goals. [Ref. 27:p. 2]

Specific DOD policy includes the following:

1. Teleconferencing activities, systems and networks shall provide interoperable capabilities to satisfy valid users' operational requirements while maintaining access control and information protection in compliance with applicable Federal laws and regulations.

2. The DOD Components shall provide life cycle management (LCM) for their teleconferencing activities and systems to include needs analysis, concept of operation to include local area teleconferencing network standards, design, development, acquisition of resources, installation, and operation and maintenance of customer premise equipment.

3. The DOD Components shall establish a focal point to serve as the principle point of contact within the Component.

4. The Defense Communications System (DCS) shall provide the telecommunications network for satisfying DOD long-haul teleconferencing requirements. All DOD teleconferencing network requirements shall be submitted to the Director, Defense Communications Agency (DCA) for satisfaction on the DCS. If the DCS cannot satisfy the requirement, the Director, DCA shall provide alternative guidance in accordance with established procedures to meet requirements and maintain interoperability within the DCS. [Ref. 27:pp. 2-3]

Additionally, teleconferencing systems must be designed for both common and multipurpose use when possible, and be centrally managed or consolidated with existing systems to the maximum extent possible. A cost effectiveness analysis is required to ascertain which system provides the best features within the allowable budget allocation. [Ref. 27:pp. 3-4]

The DOD currently has an infrastructure in place under the direction of ASD (C3I) for managing VTC. Figure 5 provides an overview of the organization. The ASD for Public Affairs (PA) and the Comptroller (C) maintain liaison with the ASD (C3I) for ensuring that VTC interoperability standards and overall policies are maintained. The NSA provides guidance on maintaining security procedures and features for teleconferencing activities, systems, and networks [Ref. 27:p. 7]. The individual DOD Components are responsible for developing VTC system requirements, providing the program planning, budgeting, and operational necessities, and acting as VTC focal points and Defense Commercial Telecommunications Network (DCTN) Contractor Technical Representatives (COTR). The DCA collects and processes all the VTC requirements submitted by the individual DOD Components, implements policies and procedures established by ASD (C3I), and maintains communication network services and standards. [Ref. 26:p. 3]

The VTC Steering Group, otherwise known as the DOD Teleconferencing Activities, Systems and Networks Steering Committee (TASNSC) plays a vital

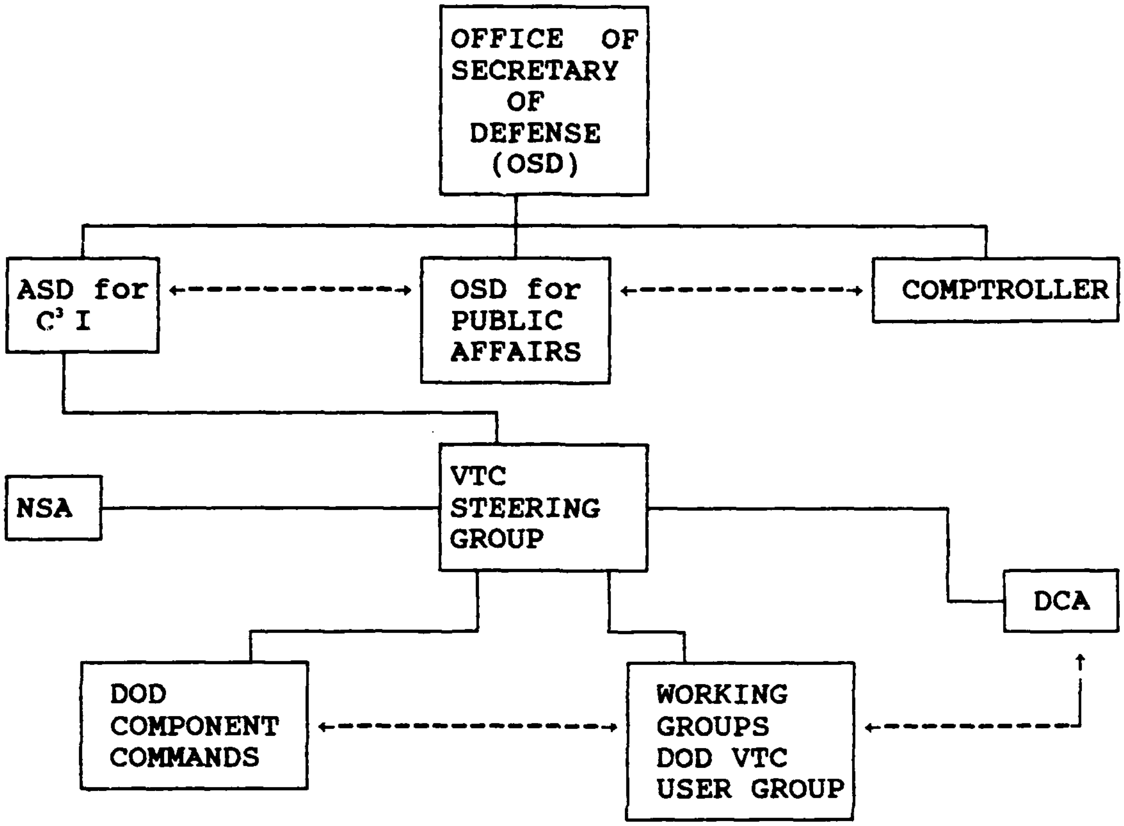


Figure 5. DOD VTC Management Structure

role in the development of DOD VTC systems. The TASNSC's primary purpose is to assist and advise the OSD and DCA on teleconferencing activities, including systems and networks policy, planning, management, standardization requirements and related issues. The TASNSC is a permanent body with members from all VTC related activities, including the Office of the Secretary of Defense (OSD), DCA, the military departments, and the intelligence agencies. The TASNSC meets quarterly, or as requested, to develop, compile, and distribute teleconferencing

user guides and information. [Ref. 27:p. 13] The TASNSC is supported by the DOD VTC Users Group, whose main purpose is to respond to inquires or tasking from the TASNSC. Additionally, the Users Group acts as a means of educating DOD users on VTC, supports enhancements to existing systems, and relays DOD VTC concerns to vendors in private industry. Membership in the Users Group is open to all military and civilian members of the DOD. [Ref. 28]

B. THE DEFENSE SWITCHED NETWORK (DSN)

The concern for the standardization and interoperability of VTC systems prompted the issuance of specific guidance by the ASD (C3I) and the Director, DCA. Based on a study of VTC standards conducted by the VTC Steering Group, other technical factors besides codec interoperability were determined to be essential for standardization. These factors include data bit rates, network control, encryption, audio bridging, and high resolution graphics techniques. The solution was not a matter of standardizing one particular technology, but one involving the entire network. This led to the establishment of the DSN as the primary network for providing VTC services within the DOD.

1. DSN Background

The DSN is a worldwide common user network with dedicated telephone services for the DOD, and the capability of incorporating data, video, and other traffic [Ref. 29:p. 1]. The DSN provides the same capabilities as the Automatic Voice Network (AUTOVON), which it replaces. These include flexible

routing of calls, hot line service, command and control conferencing, multilevel precedence and preemption. Additional capabilities provided by DSN include services for the transmission of long haul traffic normally carried by the Wide Area Telecommunications Service (WATS) and special private networks. [Ref. 30:p. 39.3.2] The DSN is designed to withstand physical attack and sabotage attempts during both peacetime and crisis situations.

2. DSN Architecture

The DSN architecture is divided into two integrated networks, the Virtual Private Line Network (VPLN) and the Private Line Network (PLN). Figure 6 shows how the two networks are integrated. The VPLN is expected to be the larger of the two networks and accommodate approximately seventy-five percent of traffic volume. This network will provide voice and data communications with military unique features similar to the precedence and preemption feature in AUTOVON. The PLN will provide near full motion, point-to-point videoteleconferencing with high speed data transmission and switched voice capability. This network will be dedicated strictly to military users. An example of a PLN is the Defense Commercial Telecommunications Network (DCTN), a wideband network using satellite and terrestrial links to support current DOD VTC requirements. [Ref. 30:pp. 39.3.2-4]

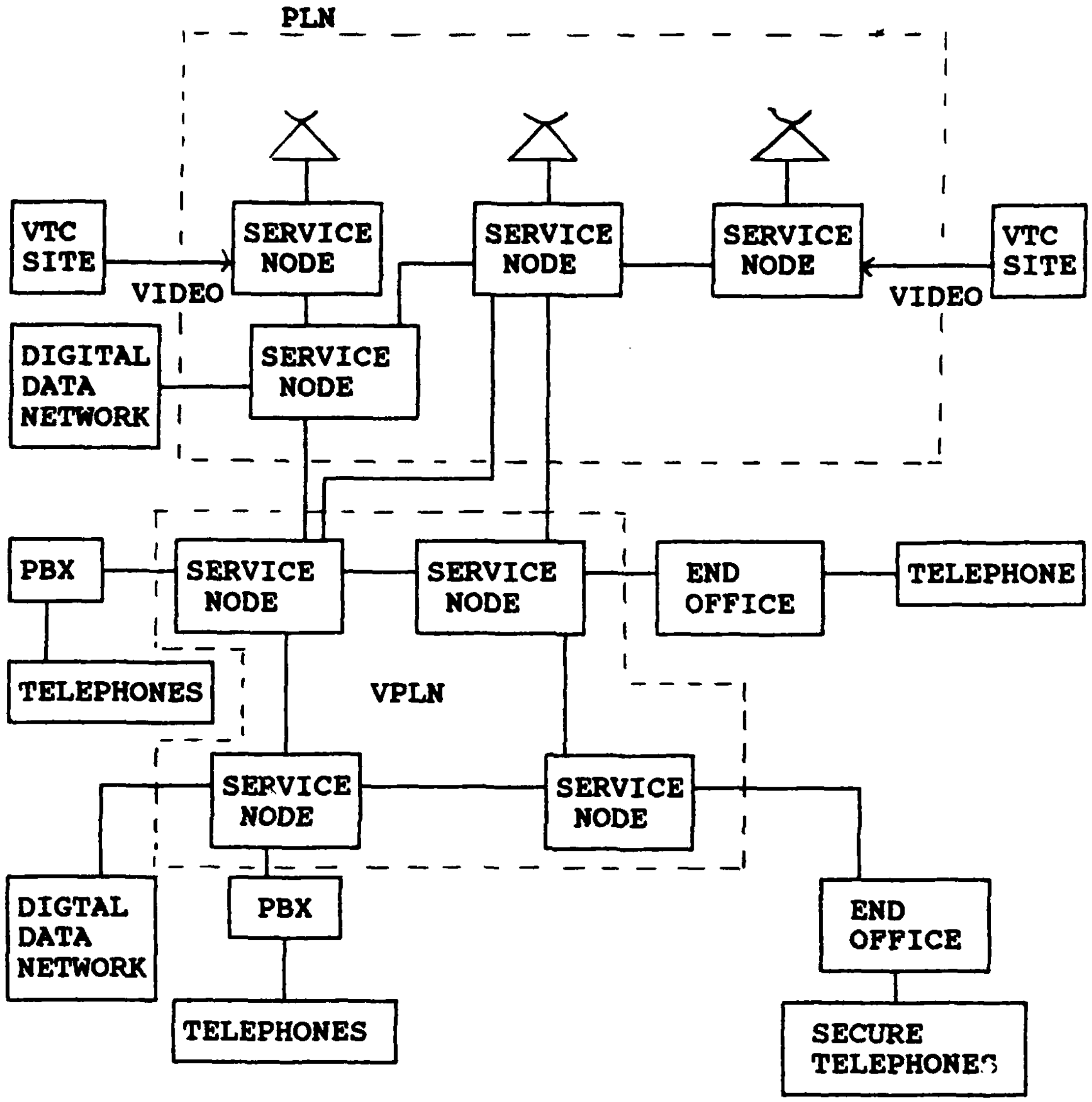


Figure 6. The DSN Architecture

3. DSN Management

The DCA oversees the operation of the DSN through the Program Manager Office (PMO). All long-haul VTC requirements within the DOD must

be submitted to this office for reconciliation. The Defense Commercial Telecommunications Network is the primary source for fulfilling these requirements. If the DCTN does not represent the most cost effective solution, then alternate arrangements are possible through the submission of a waiver request. DCA approval of the waiver for a separate competitive acquisition is based upon whether the system meets DOD VTC technical standards and interoperability requirements with the DCTN if needed. This requirement is also entered into the DSN user requirements database (URDB) for later transition into the DSN. [Ref. 26:p. 5] The DCTN has been incorporated into DSN Phase I and provides an interim service in the areas of voice, data, and VTC for administrative and command and control requirements. Once the DSN becomes fully operational worldwide, it will assume responsibility for providing services in all these areas [Ref. 31:pp. 1-2].

C. The Defense Commercial Telecommunications Network (DCTN)

The American Telephone and Telegraph Company (AT&T) was competitively awarded the DCTN contract in March 1984. The contract calls for end-to-end leased voice, data, and VTC communications service for a ten year period from 1986-1996. [Ref. 26:p. 6] The area of coverage includes the continental United States (CONUS) as weli as Hawaii, Alaska, and Puerto Rico [Ref. 32:p. 1-1]. AT&T's service is based upon a conference room or studio setup where the analog video and audio signals are compressed and multiplexed for

transmission over two 1.544 MBPS T-1 lines for duplex operation between two locations. The signal is sent to one of 28 service nodes around the country responsible for transferring the signal to its destination via terrestrial lines or satellite. Over 200 locations are currently served in the United States today. Figure 7 provides an overview of AT&T's setup. [Ref. 33:p. F5.4.4]

Satellite earth stations servicing the DCTN use TDMA terminals to access the Telstar 3, owned by AT&T, which provides a 60 MBPS multi-transponder network for efficient, flexible and economic transmission capability between nodes. The AT&T staff operates the DCTN Network Control Center (NCC) in Dranesville, VA, which provides network control, operation, and maintenance. Network control is maintained by two software packages, the Network Control Alarm and Maintenance System (NCAMS) and the Special Services Management System (SSMS). NCAMS controls the satellite portion of the network and implements the TDMA data transmission assignment provided by the SSMS. The SSMS is the major interface for network reservations. [Ref. 34:p. 50.4.2]

1. DCTN Modes of Operation

The DCTN has three modes of operation. These include point-to-point, broadcast multipoint, and interactive multipoint. Point-to-point permits fully interactive, two-way video and audio conference between two sites. The broadcast mode allows a one-way transmission of audio and video from one conference site to two or more other sites. This method has also been referred to as

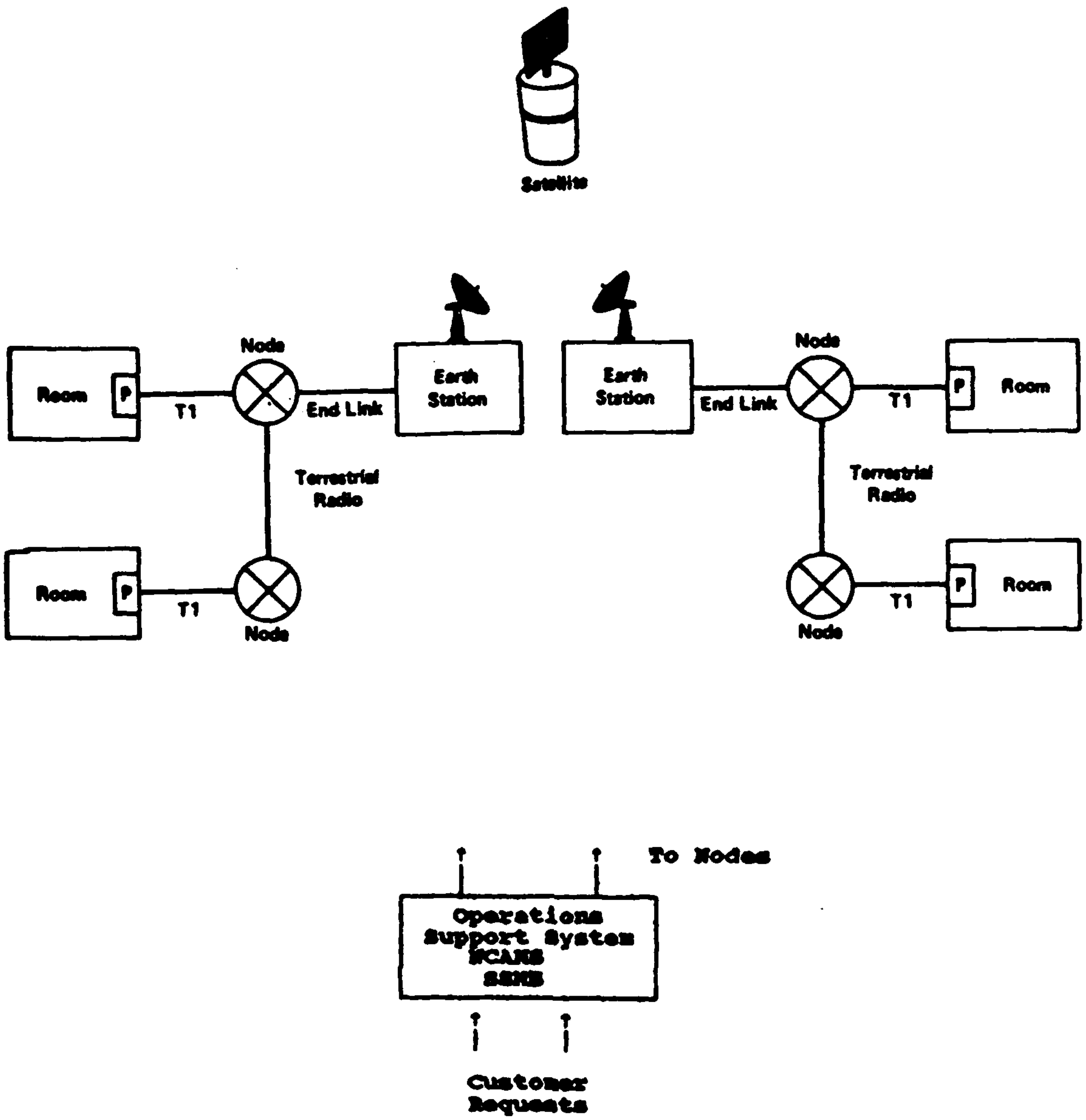


Figure 7. AT&T VTC Overview

telebroadcast or teleseminar, depending upon the application. The third mode, interactive multipoint, is the most sophisticated and employs simultaneous video transmission from two conference sites. With interactive multipoint, one video channel is assigned to the conference chairperson's site and the second channel is assigned to other sites during the conference as directed by the conference chairperson. Other sites receive the chairperson's video or the speaker's video as selected by the chairperson. Audio is maintained continuously throughout the conference with a separate fully interactive audio bridge for non-secure VTC only. [Ref. 32:p. 1-2]

The video network, audio bridging, and control channel connectivity requirements are established by the SSMS software at Dranesville in advance of a scheduled conference. A permanent simplex channel is provided to the chairperson's site for controlling the video. The other simplex video channel is assigned as needed at each station by a reassignment of the shared uplink as the conference proceeds. Conference room or studio control of the VTC is provided by the Session Control Panel (SCP) which is linked to the Video Teleconferencing Switching Controller (VTSC) at the earth station node via the Video Conference Controller (VCC).[Ref. 32:p. 2-1]

Multipoint audio is provided by two methods. The first method is used for unclassified conferences and employs a distributed or central bridge with an audio link separate from the video. The other method is used when security issues

require the use of government furnished encryption devices at the conference sites. With this method, the audio and video signals are combined and transmitted from the chairperson and broadcaster location as directed by the chairperson. Audio is not fully interactive. Participants hear speech only from the room they are viewing, which is termed the "Seen-to-be-Heard" secure multipoint approach. [Ref. 32:p. 2-2]

2. VTC Network and Physical Security

Network privacy is provided by Digital Encryption Standard (DES) encryptors at the DCTN earth stations. Conference security is provided for point-to-point mode by KG-81's or KG-94s/94As encryption devices at studio locations. Physical security of the conference sites is equally as important as transmission security. Studios must have controlled access with alarms built-in to detect intrusion. The studio setup must also ensure that electromagnetic transmissions do not emanate outside of the studio and be a source of compromise for classified material. [Ref. 32:p. 1-2]

3. Studio Configuration and Network Interface

Studios are connected to the data transmission lines by the SCP, VCC, a modem, Data Protocol Converter (DPC), and the encryption configuration control equipment. Figure 8 depicts a generic DCTN studio configuration and network interface [Ref. 32:p. 2-4]. A CLI Rembrandt codec receives the analog video and audio data from cameras, graphics, and microphones via the studio

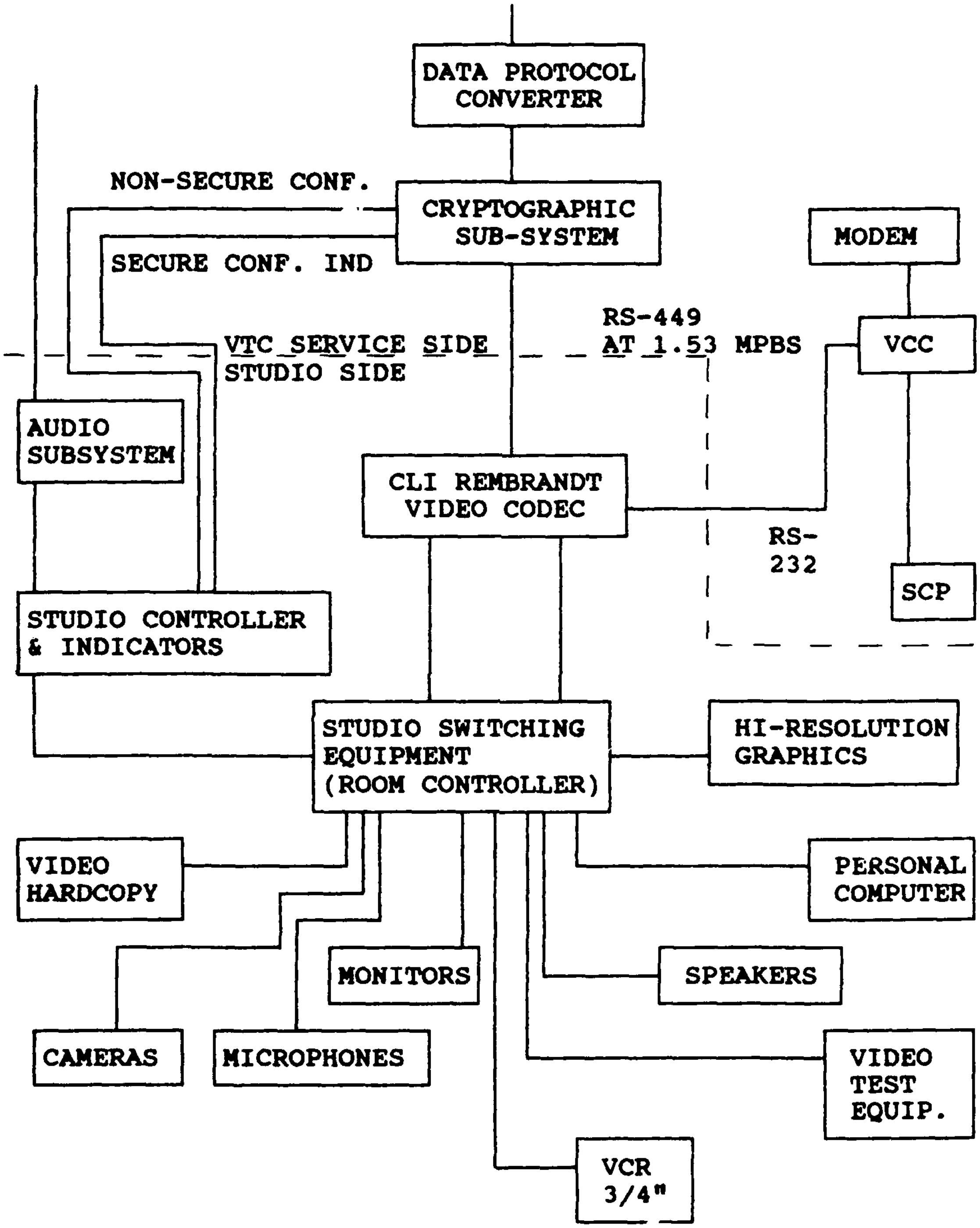


Figure 8. Generic DCTN Studio Configuration

switching equipment and performs the analog to digital conversion, data compression, and multiplexing. If the conference is secure, the data stream is encrypted and sent through the DPC to provide the necessary network data compatibility requirements. For non-secure conferences, the data stream is sent directly to the VCC for transmission via a modem. The Rembrandt codec also performs the decompression, demultiplexing, and digital to analog conversion on the incoming data stream and transfers the analog signals to monitors, speakers, visual display devices, standard or optional high resolution graphics, and video hardcopy. Interim DCTN standards for the video codec, video bit rate, conference control equipment, and high resolution graphics were updated in July 1989 to ensure compatibility between DCTN studios and non-DCTN studios [Ref. 26:p. 18]. The studios are provided by a DCTN contractor or installed by individual subscribers.

4. DCTN Interoperability Requirements

Interoperability standards have been established for the video codec, the audio subsystem, high resolution graphics, and facsimile. The Rembrandt codec has been adopted as the interim DCTN standard until the CCITT decides upon a universal codec standard. The Rembrandt codec also supports the audio requirements for point-to-point or broadcast conferencing modes by multiplexing the audio signal onto the T-1 digital bit stream. For multipoint conferences, the audio portion is provided by separate channels using an audio conferencing bridge

provided by the DCTN contractor. Voice transmissions are sent at 64 KBPS which provides a bandwidth of 300 Hz to 7000 HZ. [Ref. 32:p. 3-4] No standards currently exist for the use of high resolution graphics either. The Databeam model CT 1000H has been selected by competitive process as the interim standard for DCTN interactive graphics. [Ref. 32:pp. 3-4,5]

The facsimile industry has established adequate standards to ensure interoperability between equipment of most manufacturers. Facsimile is useful in studios where high resolution graphics is not available. The use of facsimile is limited to unclassified information only and can be transmitted over a standard telephone line or multiplexed into the Rembrandt codec. The codec sends the data via a modem at 9.6 KBPS for point-to-point conferences only. [Ref. 32:p. 3-5]

The DCTN is structured to support various communities of interest (COI). A COI is an organization, group of organizations, or parts of organizations utilizing a system in pursuit of common objectives [Ref. 27:p. 14]. For example, a COI may include all VTC capable Forces Command (FORSCOM) or Naval Air Systems Command (NAVAIR) installations. Limited inter-COI conferencing is available. Normally, FORSCOM would not be able to hold a conference with NAVAIR because of the DES encryption requirements established by the NSA. However, planned upgrades for fiscal year 1991 will provide full interoperability between COIs. [Ref. 26:p. 15]

The DCTN is capable of providing access to defense contractors for VTC connectivity with their DOD program/project managers through standard DCTN connections, off-net, or A/B switched service. The standard DCTN service involves a direct connection to the network similar to any other DOD subscriber. The same capability for secure and non-secure service, point-to-point or interactive multipoint, and dedicated T-1 service is provided. The off-net service permits the contractor to access the DCTN on his own preferred carrier through a contractor access point (CAP) gateway. The CAP, which performs the necessary data protocol conversion, provides point-to-point capability only. A multipoint upgrade is under consideration. Preferred carrier satellite use is not recommended due to the transmission delays and echo problems associated with double hop satellite usage. [Ref. 35:pp. 1-2]

The final option for contractor access to the DCTN is provided through an A/B switch for temporary access and special requirements. In this setup, a DCTN VTC studio is connected to the DCTN via switch B and to another network or studio on switch A. Depending upon the conference locations, a particular DCTN subscriber may choose the desired connection by selecting either the A or B switches. Figure 9 provides a description of the various accessing methods for the DCTN. [Ref. 26:p. 17]

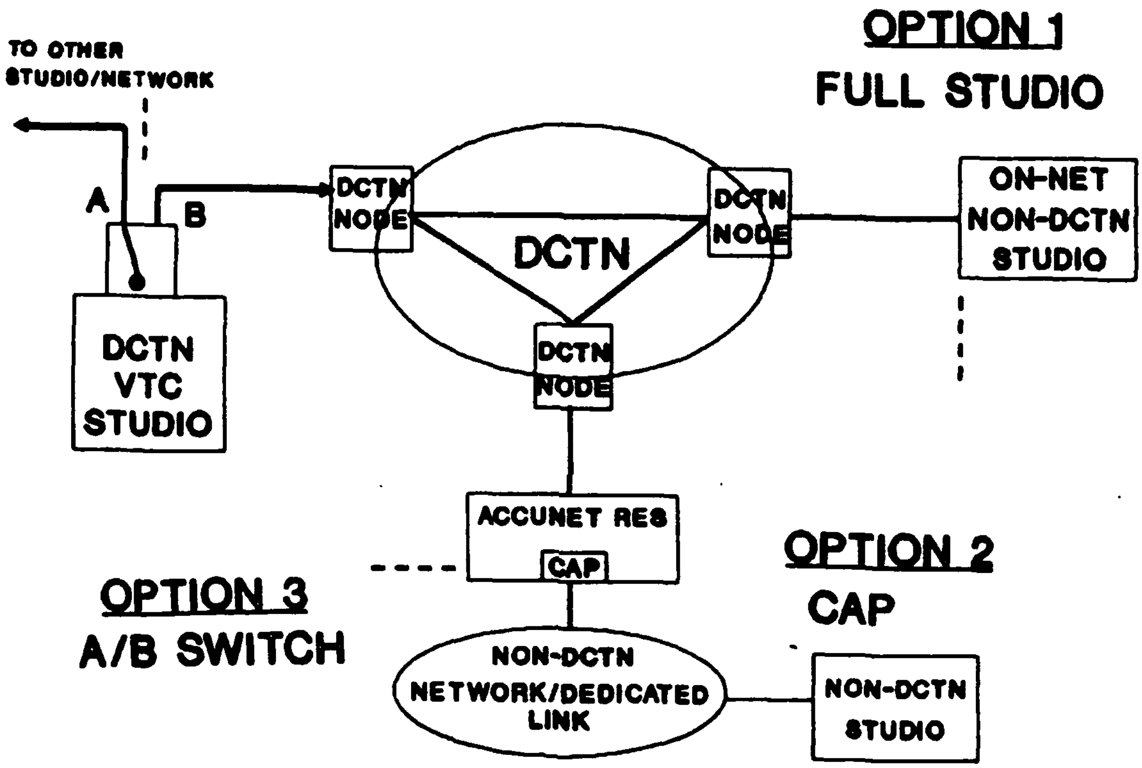


Figure 9. DCTN Accessing Options

5. Bulk Data Transfer Over DCTN VTC Facilities

The DCTN is a private line network incorporated into the DSN for providing leased video, voice, and data communications services. Rather than keep the digital transmission facilities idle during non-VTC time slots, the DCTN can be used by subscribers to transfer bulk data requirements to their servicing Automated Data Processing (ADP) facilities. This capability is meant to augment the Defense Data Network (DDN) program, not replace it. Requirements to transfer bulk data are submitted to DCA using a standard Telecommunications Service Request (TSR). Bulk data transfer is allowed only within a COI, and the actual transfer must not interfere with VTC applications. [Ref. 36:p. 1]

6. Scheduling DCTN Services

Reservations for DCTN VTC services are made with the NCC at Dranesville, VA. If required, a VTC may be arranged between 15-30 minutes prior to the conference. Once the reservation has been made, operators interface with the SSMS to establish the required network alignment. Reservations are also made for transferring bulk data on a not to interfere basis with VTC.

7. Contract Specifications for the DCTN

In accordance with the government contract, the DCTN must be available 99.5 percent of the time on a monthly basis, excluding government power outages. The quality of the connection should be equivalent to a switched

voice circuit with a data bit error rate of one in 10^{-7}. Maximum delay restriction is limited to a one satellite hop end-to-end. [Ref. 26:p. 10]

8. Planned Future Capabilities of the DCTN

One of the restrictions imposed upon the DCTN is the lack of full interoperability between COIs. With this one restriction lifted, the DCTN could become a true common user network. A proposal from AT&T would modify DCTN privacy keying material policy for each community of interest in the DES at the earth stations. DCA has subsequently discussed this particular issue with the NSA, and full interoperability is expected in the near future. [Ref. 37:p. 6]

Selectable VTC rates from 56 KBPS to 1.544 MBPS is another enhancement being considered. Low bit rate tests with 768/384 KBPS were conducted by two Army COIs in 1988. The study results showed that the 384 KBPS data rate was not suitable for conference room or studio applications. The poor picture resolution and blurring of motion were the two most common complaints. However, the 768 KBPS data rate was suitable for conference rooms, and the resolution was rated equal to that experienced with 1.544 MBPS data rate. [Ref. 37:p. 1]

The DCTN will implement industry and international VTC standards when they are established. In particular, the video codec standard of 64 KBPS will be the standard for the DCTN when approved by the CCITT.

The DCA plans to make available international gateways that will provide the necessary data protocol conversion for accessing VTC studios in foreign countries. Other important enhancements for the DCTN include:

1. Automated reservation services
2. Improved network management capabilities
3. Fully interactive multipoint secure conferencing
4. Access to mobile/remote/temporary users [Ref. 26:p. 20]

D. U.S. NAVY VTC SYSTEMS

The Navy VTC program falls under the auspices of the Assistant Vice Chief of Naval Operations (OP-O9B), who is responsible for developing the Naval Visual Information (VI) program and establishing policy for its use. Visual Information primarily involves audiovisual production, photography, VI technical documentation (including combat camera), and VTC. The Assistant for Naval Imaging (OP-O9BG) implements the Naval VI program and develops VI policy. He is responsible for coordinating Navy VTC requirements with major commands and the DCA, authorizing VI activities, and providing guidance for management and operation of VTC activities. A working group has been chartered by OP-O9B to develop a Navy directive on VTC. The working group includes

representatives from the Office of the Chief of Naval Operations for Command and Control, OP-O9BG and the Naval Data Automation Command. [Ref. 38:pp. 2-3]

Navy VTC systems have been implemented at a total of twenty-five locations with fourteen being operational, five being installed as of October, 1989, and six in a temporary status. The Naval Air Systems Command (NAVAIR) employs VTC at seven sites throughout the U.S. using the DCTN and facilities supplied by AT&T through the DCTN contract. The eighth unit is mobile, and designed for transportation on a flat bed truck. It can support up to twenty participants. When the unit is located at its destination, it is connected to T-1 digital lines for data transmission. This represents one of the few mobile systems in use within the Navy today. [Ref. 38:p. 5]

The Naval Supply Systems Command (NAVSUP) employs VTC between sites located in Mechanicsburg PA, Philadelphia PA, Washington DC, and Charleston SC. This system is DCTN compatible and uses the SPRINT meeting channel to permit three way conferences with continuous presence of participants. [Ref. 38:p. 6] The Naval Sea Systems Command (NAVSEA) uses a leased T-1 line to communicate between Washington DC, Newport RI, and New London CT. Satellite services are used to communicate with facilities in Bath ME. This network is also compatible with the DCTN and has bridging capabilities to connect with other networks. [Ref. 38:p. 8]

The Commander Training Command Atlantic (COMTRALANT) has implemented a VTC system to conduct teletraining of Navy courses of instruction between subordinate sites in Norfolk VA, Dam Neck VA, Charleston SC, Mayport FL, and Newport RI. This network, the COMTRALANT Electronic Schoolhouse Network (CESN), provides multipoint security using a leased satellite service with the GTE Spacenet Corporation. Over thirty-two courses are capable of using this technology for classroom instruction. Any of the five sites have the capability of hosting and teaching the course to the other sites. Commander Training Command Pacific (COMTRAPAC) has a similar network for teletraining between San Francisco and San Diego CA. [Ref. 38:pp. 10-11]

E. FUTURE DEFENSE DEPARTMENT VTC SYSTEMS

1. The Joint Worldwide Intelligence Communications System (JWICS) VTC Network

The Defense Intelligence Agency (DIA) has determined that the use of VTC systems will improve the timeliness and accuracy of intelligence information transferred between individual intelligence and warning centers. The JWICS VTC network has been designed to provide telebroadcast, point-to-point, or point to multipoint conferences to nineteen locations within the United States and overseas. [Ref. 39:p. 1] Two or more deployable JWICS VTC facilities are also planned. Additionally, this network will be designed to have full connectivity with the existing Washington area Secure Video Teleconferencing System (SVTS), other

intelligence command sponsored VTC networks, and future joint and service command VTC systems. Figure 10 shows the JWICS VTC Network and connectivity [Ref. 39:p. 53].

The JWICS Network will feature an accessing scheme similar to calling long distance by telephone. Therefore, individual sites will be able conduct routine conferences without gaining permission from the net control authority, the Duty Director of Intelligence (DDI) at the National Military Intelligence Center (NMIC). A precedence dialing feature similar to that used in the AUTOVON system will ensure that higher authorities have access to distant sites on a priority basis. During periods of emergencies or national crisis, the net control authority will retain access control for all subscribers. [Ref. 39:p. 54]

The JWICS network will be used for daily intelligence briefings and short notice conferences in response to emergencies. A typical day on this network would entail worldwide briefings from various sites depending on their time zones. A briefing from the United States Forces Korea (USFK) command would start the day, followed by the European Command (EUCOM), Joint Chiefs of Staff (JCS), and finally the Pacific Command (PACOM). All these briefings would be taped at each site for playback at a later, more convenient time.[Ref. 39:p. 55] Each JWICS site will be designed to accommodate two or more simultaneous conferences that will enable conference participants to receive the daily intelligence briefing broadcasts and respond immediately to incoming, real time

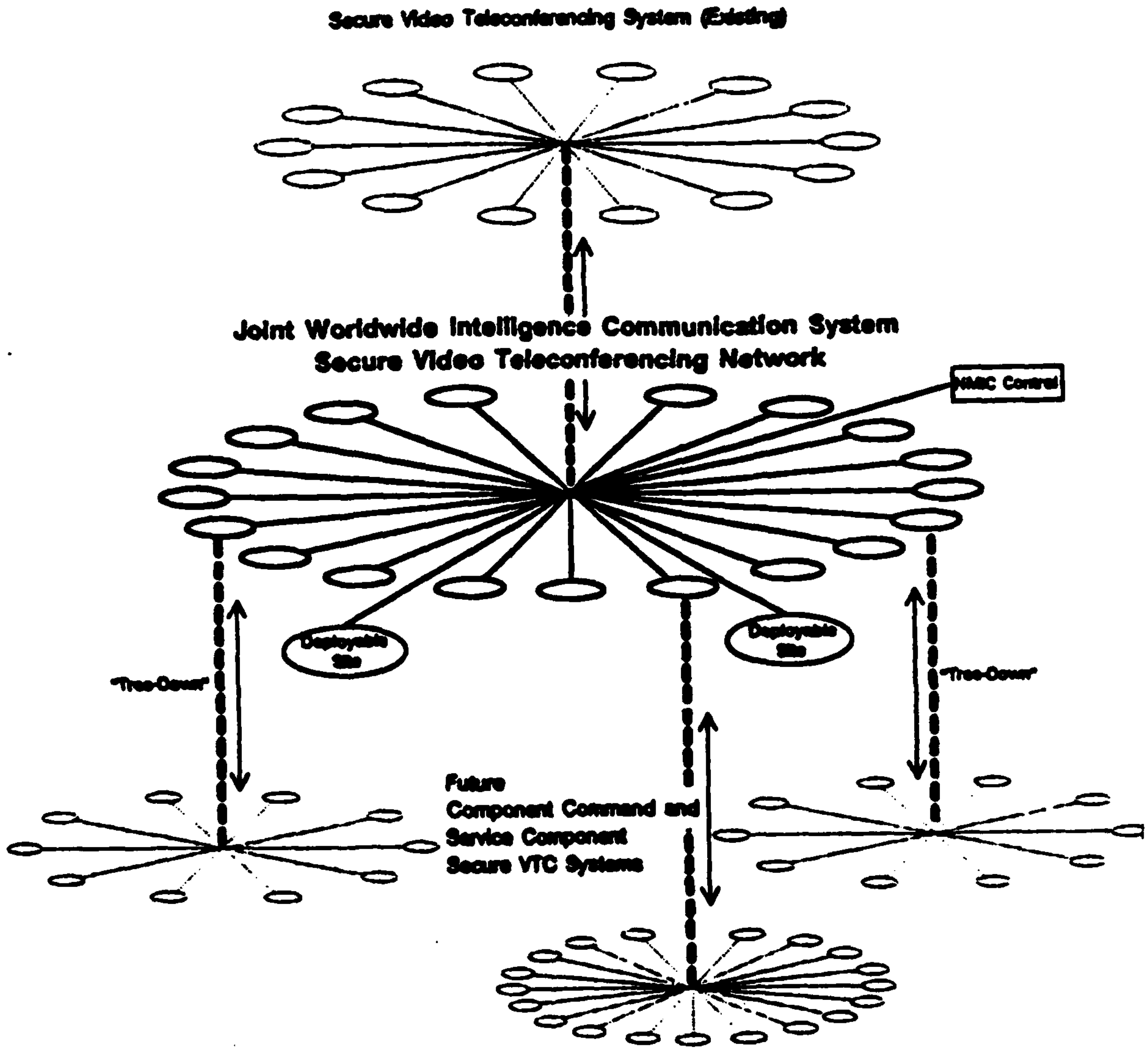


Figure 10. JWICS Network and Connectivity

intelligence data. Follow-on JWICS planning calls for the use of small, desktop VTC systems with simultaneous conference capability that can be used aboard ship or in a land based crisis location. [Ref. 39:p. 56] These systems will be highly dependent on satellite coverage within their area of operations.

Miscellaneous features of the JWICS Network will include the capability to transmit bulk data like the DCTN, to support classified information up to Top Secret/Sensitive Compartmented Information (SCI), and to provide high resolution graphics to support unique intelligence data distribution requirements. The watch center will function as the VTC studio with the required lighting, microphones, cameras, speakers, and monitors installed. All components and sub-systems will be procured directly from the manufacturers, thereby eliminating any research and development costs.[Ref. 39:pp. 58-66]

2. The Oahu Secure Video Network

The Oahu Secure Video network is designed to be compatible with the planned JWICS Network and other existing intelligence networks. The objectives of this system are to provide an integrated intelligence network between the U.S. Pacific Command (USPACOM) intelligence centers on Oahu and to support joint military operations with other services as required. [Ref. 40:p. 1] Commands identified as subscribers on this network include the U.S. Commander-in-Chief Pacific (USCINCPAC), the Intelligence Command Pacific (IPAC), Headquarters Pacific Air Force Command (HQ PACAF), and Commander Western Command

(CDRWESTCOM) [Ref. 40:p. 4]. The system will use similar off-the-shelf equipment projected for use with JWICS to ensure interoperability.

The Oahu Secure Video network will also be compatible with existing mobile facilities such as the Enhanced Crisis Management Capability (ECMC). The ECMC is an alternate command post which is transported by a C-141 aircraft. The ECMC provides mobile communications and automated data processing support to command staffs operating in remote locations. Communications capability includes both UHF and SHF MILSATCOM access. Implementation of secure VTC in the ECMC could be included as part of the phased acquisition of the Oahu network. [Ref. 40:p. 6]

The Mitre Corporation has researched the VTC Secure Network issue for USCINCPAC and has compiled recommendations for connectivity between the various subscribers. The use of the DCTN was recommended for the following conferences:

1. Commander-in-Chief (CINC) to JCS
2. CINC to other CINCs
3. CINC to local sites

Since the Telstar satellite constellation provides coverage to Hawaii and the mainland, the DCTN can support these requirements. For real time, limited

motion VTC with off-island subordinates in Japan, Korea, and the Philippines, the issue is one of determining the best connectivity from a number of alternatives including the DSCS, commercial satellites such as INTELSAT, or the Defense Data Network (DDN). [Ref. 41]

F. THE COMPATIBILITY OF EXISTING AND PLANNED VTC SYSTEMS WITH AFLOAT APPLICATIONS

The afloat VTC system brings with it a number of restrictions primarily as a result of the available transmission media. This section provides a comparison of the DCTN, Navy, and JWICS/Oahu Secure Voice Networks to determine which one can be readily adapted to the afloat system.

The DCTN is not readily adaptable to an afloat VTC system due to the use of commercial satellites, the use of studio setups at conference sites, and the reservation process. The DCTN uses the Telstar 3 satellite whose coverage is limited to the continental United States, Hawaii, Alaska, and Puerto Rico. Based on coverage alone, use of this satellite is acceptable only in relatively close off-shore areas in the Atlantic and Pacific Oceans. Consequently, this satellite is not available for use in long haul transmissions from the Mediterranean Sea, the Western Pacific, Indian Ocean, and the polar regions. Any attempt to use more than one satellite to provide the necessary coverage could result in excessive transmission delays and unacceptable video and audio degradations. The DCTN is limited to a one satellite hop transmission.

The use of Telstar 3, or any other commercial satellite, requires additional shipboard equipment to support the C and Ku frequency bands that are employed. The problem with using C band satellites is that they are heavily used by private industry and thus it would be difficult to reserve cost effective transponder space. The Ku band satellites offer more bandwidth and flexibility, but they are subject to greater transmission degradations as a result of precipitation and other atmospheric conditions. Therefore, the installation of additional equipment aboard ship to support VTC with commercial satellites would not be the optimal choice.

The DCTN is based on a conference room or studio setup with relatively large monitors for viewing other sites. With the limitations on available bandwidth and communication circuit requirements in military satellites, DCTN full motion video at 1.544 MBPS does not represent the most efficient use of a satellite's capabilities. If the DCTN were compatible with the MILSATCOM system, the DCTN would be required to accommodate variable bit rates to provide the connectivity between afloat users and shore sites. The problem then becomes a matter of acceptable video at the studio. The use of lower bit rates, 56 KBPS to 384 KBPS, may be acceptable for a desktop model, but is marginal for larger sophisticated monitors used in studios due to excessive motion blurring and poor resolution.

The use of the reservation system employed with the DCTN is acceptable for meetings that are planned over a length of time. However, the reservation

process is not well-suited for the variety of real-time requirements that may be expected in an at-sea environment.

The DCTN provides two features that could benefit the afloat user. They include defense contractor access and bulk data transfer capabilities. Defense contractor access, if applied to a network for afloat VTC, would greatly improve the repair capabilities of numerous shipboard systems by ship's personnel. Rather than sending a long hard copy message to the responsible Navy Systems command, the ship can avoid the middle man and speak directly with the contractor who designed and built the system.

The VTC systems that show promise for afloat connectivity are the JWICS and Oahu Secure Video Network for the following reasons:

1. The JWICS Network will provide relatively quick access to subscribers via a dial up type service to support emergent communications requirements.

2. The use of a precedence feature provides critical network availability for higher authorities while maintaining the net as a common user, access on demand circuit.

3. The conduct of intelligence briefings over the network from various command posts around the world is the primary network objective and would also benefit the afloat commander.

4. Security capabilities are well within the scope of information expected for transfer between the afloat user and shore facility.

5. The plans for the JWICS and Oahu Secure Video Networks both include the possibility of adding mobile units to the networks.

6. The Intelsat commercial satellite and the Defense Satellite Communications System could provide the connectivity, but the DSCS is the most likely choice because of the shipboard equipment requirements.

7. The co-location of Fleet Commanders with intelligence commands provides ready access to higher authorities for VTC requests via a JWICS terminal from afloat units.

Finally, the VTC systems currently in use within the Navy have little compatibility with an afloat system. Systems sponsored by NAVSEA, NAVSUP, and COMTRALANT support specific command objectives and often use commercial systems with a DCA approved waiver. Therefore, current Navy systems are not expected to provide a VTC capability to afloat users.

G. CHAPTER CONCLUSION

This chapter provided an overview of the policies and objectives for using VTC systems within the DOD. The primary objective established by the ASD (C3I) is to ensure that all system acquisitions be interoperable with existing networks. Therefore, the DSN was established as the only network designated for VTC use. The DCTN was programmed to provide interim VTC capability until the DSN becomes fully operational.

Examples of various VTC networks in place or planned was discussed to illustrate how these systems support their own Communities of Interest. The JWICS and the Oahu Secure Video networks are in the planning stage and could provide connectivity with afloat users for VTC. The next chapter discusses the

needs of the afloat user for VTC and provides a generic system that would be compatible with the JWICS and Oahu Secure Video networks.

IV. AFLOAT USER REQUIREMENTS AND VTC SYSTEM DESIGN

Research into the technical feasibility of implementing VTC aboard afloat units revealed that existing military satellites could support the required data rate for limited motion and near full motion video. The necessary channel capacity depends upon the PSK modulation technique, which is particularly important considering the narrowband capability of the FLTSATCOM system. Limited motion could be accommodated at 56 KBPS on a narrowband channel using the QPSK technique. The DSCS III program, however, is better suited for full motion video requirements because it provides ample bandwidth and greater flexibility than the FLTSATCOM system. The only drawback is that DSCS III capability is currently limited to or planned for flag configured units only.

Chapter three discussed the major VTC systems and networks in use within the DOD today and those planned for future implementation. The DCTN is not readily adaptable to afloat user requirements since it employs commercial satellites and large studios where lower bit rate or limited motion video may result in viewer dissatisfaction. Other Navy systems are designed to meet individual command initiatives and have little compatibility with afloat needs. The JWICS shows promise for implementing an afloat terminal into the network. The actual

terminals and transmission media planned for JWICS could provide the necessary ship-shore connectivity requirements.

This chapter discusses VTC's possible applications aboard afloat units and focuses specifically on command and control and intelligence sharing requirements. Once the user's needs and possible VTC applications are established, the DOD baseline VTC system and options will be discussed. Next, the author's view of an afloat VTC system is provided that will not tax limited shipboard space and weight limitations yet still provide adequate connectivity with shore facilities. The chapter concludes with a brief scenario of how this VTC capability could enhance the operation of an afloat user both inport and underway.

A. DETERMINING AFLOAT USER REQUIREMENTS

VTC need assessment is often performed by a team that conducts surveys of possible end users, analyzes the data, and recommends the system best suited for supporting communications requirements within the organization. Civilian corporations build their own need assessment teams or hire outside consultants specializing in VTC applications to conduct the survey. The Keiper Associates have performed VTC consulting services for the Department of Defense.

The VTC need assessment consists of a survey or questionnaire that is completed by all potential users. The questionnaire focuses on departmental functions and the types of meetings held. The meetings are categorized by purpose, frequency, and duration. Additional information on how the meetings

are conducted, number of sites and people involved, and visual aid requirements is obtained with the questionnaire. [Ref. 42:p. 54] The VTC need assessment is often augmented by a review of VTC vendor material, attendance at VTC seminars and conferences, and site visitations where a VTC system is installed.

An afloat VTC need assessment would likely focus on the individual users and the types of communications that would benefit most from videoteleconferencing. Individuals benefiting the most include the commanding officer, executive officer, and department heads. The Commanding Officer's VTC requirements would focus on the ability to attend critical meetings for disseminating intelligence and discussing strategy prior to getting underway or while enroute to a particular operation. The Operations Officer's VTC requirements would focus on the ability to attend pre-sail conferences without leaving the ship and providing more timely and accurate reporting of critical incidents at-sea and inport. Other department heads and crewmembers may have a need for VTC systems, particularly those involved with equipment maintenance and repair work. They would have direct access to technical facilities ashore to assist in troubleshooting of faulty equipment.

The second area of concern in the VTC need assessment is the identification of critical communications that are essential to national security and the mission of the afloat unit. The Navy has established specific guidelines for the voice and hard copy reporting of critical incidents involving the environmental safety and

national security of the United States. These incident reports are candidates for VTC because of the amount of information required and possible ambiguity surrounding those particular situations. [Ref. 42:p. 58-59]

The need assessment must accurately reflect the organization's VTC requirements to avoid potential problems caused by inappropriate system design and low user acceptance. VTC programs may fail as a result of placing too much weight on the technology and not enough on the implementation of that technology within the organization. VTC programs also fail because the communication capabilities were not accurately evaluated or systems were implemented from designs used specifically for other organizations. [Ref. 43:p. 3]

In summary, a VTC need assessment must consider who the users are as well as the command's mission and communication requirements to determine if VTC can improve overall organizational effectiveness [Ref. 43:p. 13]. The next section describes some VTC applications that may enhance an afloat unit's ability to perform its assigned mission and communicate with higher authorities.

B. VTC APPLICATIONS FOR AFLOAT USERS

1. Background

Recent events involving U.S.Navy units indicate the growing importance of video information in reporting significant occurrences. These events include the Libyan operations in 1986 and the U.S. Naval presence in the Persian Gulf during the war between Iraq and Iran. The significant amount of press coverage

and the policy of allowing national news agencies to ride afloat units during Persian Gulf patrols indicate a growing demand for video information in the military and civilian sectors. With the implementation of a VTC system aboard ships, the video information transfer to higher authorities can occur without editing and on a near real-time basis. The most important types of information that could be passed via VTC involve the use of command and control and intelligence sharing communication channels.

a. Command and Control Applications

Command and control is defined as the process and equipment required by a commander for issuing commands and exercising control over assigned forces during battle. Command and control systems require communications links, a structured organization and interoperability. The communications channel is the necessary link between the command center and the forward deployed unit. This communications link must provide a reliable and accurate depiction of the situation on a real-time basis so that timely and accurate decisions can be made on the employment of forces. [Ref. 44:p. 2-5]

Command and control systems support various organizational structures, including those that are centralized, distributed, and hierarchical. The structure used most often in the military is hierarchical, where a central site controls each subordinate through various sub-elements or commands functioning independently or in tandem. Figure 11 provides a flow diagram of

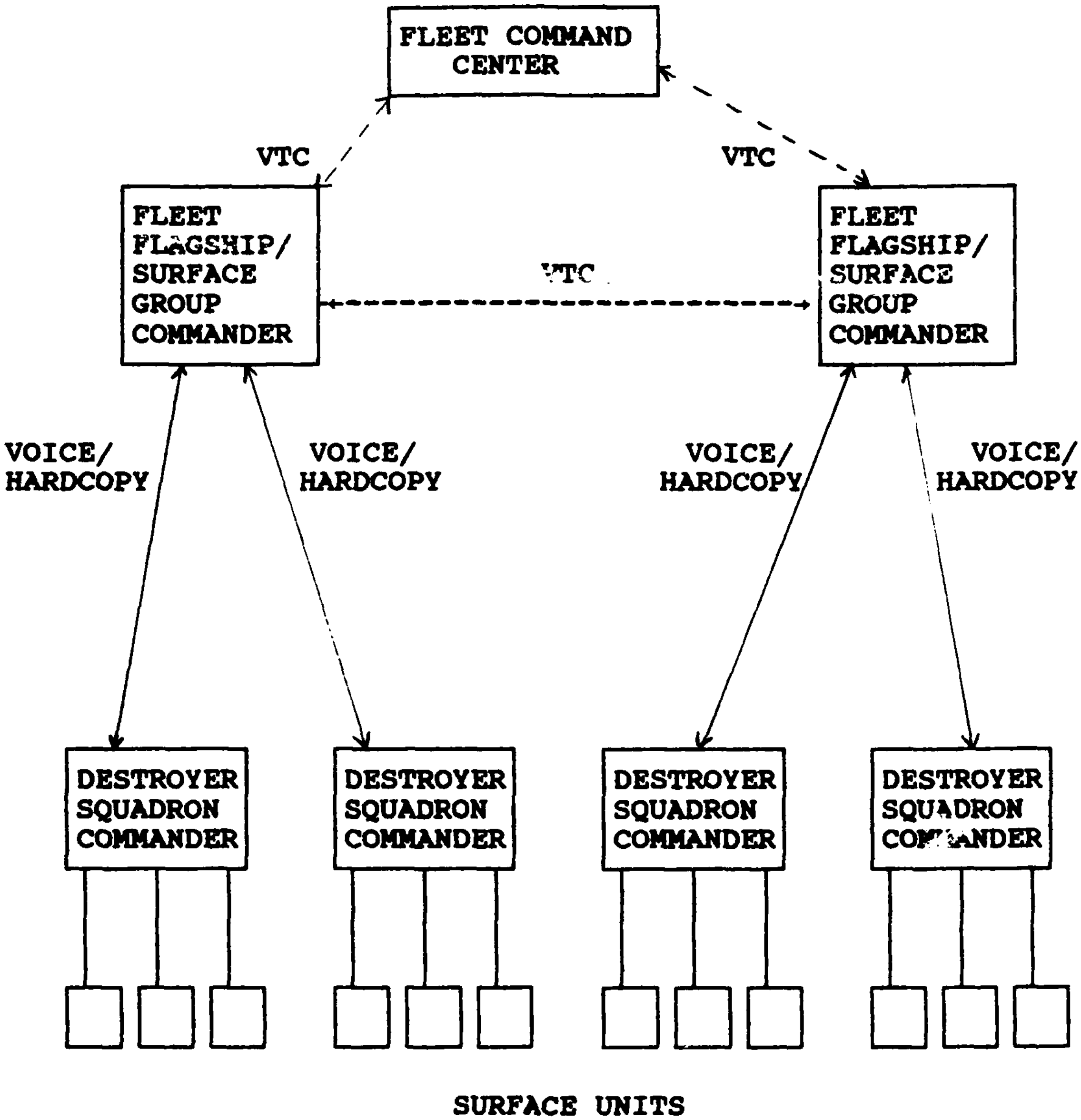


Figure 11. VTC Communications Within a Hierarchical Organization

communications within a hierarchical organization using a VTC system. The communications channel must provide the information flow within this structure to ensure cognizant commanders are well-informed and able to make the optimal decision at all levels. [Ref. 44:p. 7] Videoteleconferencing offers the opportunity for commanders to meet in group sessions, despite physical separation, and discuss strategy. Discussions may occur between fleet commander and group commander or between individual group commanders regarding specific tactics and coordination procedures.

A command and control system must be interoperable with other systems to accommodate communications flow and permit the two systems to operate together. The interoperability issue is a concern with VTC systems as well since organizations using different codecs are presently unable to share information.

The real-time uncensored nature of VTC systems presents numerous applications in the area of command and control. Time sensitive information can be provided through face-to-face impromptu meetings or live action video. Face-to-face meetings may be used to discuss current and future strategy for engaging a hostile force. Externally mounted or mobile cameras may be used to transmit video of close-in action or battle damage to immediate superiors. A videotape from a ship in company may be transferred to

the flagship for transmission to the command center, providing a near real-time account of their situation.

The use of video presents certain advantages over current command and control reporting procedures. Currently, an incident report is submitted first by a formatted voice report and followed by a formatted hard copy message reporting the situation in greater detail. Subsequent reports are submitted to provide command centers with amplifying information as necessary. This process is sequential in nature and causes certain delays in getting the information up the chain of command [Ref. 45:p. E.4.4.5]. A command submitting an incident report must first gain voice contact with the specified command center and simultaneously draft and transmit a hard copy report within the required time frame. A videoteleconference, however, could provide more information in less time than the current means of incident reporting. Assuming demand access capability within a satellite network, a videoteleconference can be established within minutes of the incident. The result is more information on the incident for higher authorities and more efficient use of communications channels, since only one circuit is required.

The current incident reporting process also lends itself to an individual's interpretation of the situation which may not accurately reflect the seriousness of the problem. VTC could provide unfiltered data along with the

personal accounts of the on-scene commander to help alleviate the problem of personal interpretation clouding the facts surrounding an incident.

Additionally, the use of a computer in conjunction with a VTC system would allow the afloat user to draft a hard copy report and display it on screen for review by higher authorities. If the report satisfies the requirements of all viewers, then it can be transmitted by a normal file transfer protocol or via standard communications channels if additional addressees are required.

The disadvantage with an afloat VTC system is the excessive bandwidth requirements. VTC systems require more bandwidth than existing command and control circuits. However, VTC conducted at lower bit rates may provide acceptable picture resolution for a desktop version and reduce the bandwidth requirement. Multi-bit rate codecs are used to provide the necessary flexibility. If bandwidth is available, conferences may be conducted at higher bit rates. If bandwidth is not available, the conference may still occur with some degradation in video quality.

In summary, the use of VTC in a command and control circuit can provide the real-time transfer of video information and an individual's account of the situation during a face-to-face discussion. The use of video information may provide a greater understanding of the situation and assist the decision maker in formulating the optimal plan of attack. Actual reporting time may be reduced by eliminating the sequential nature of incident reporting and using one

communications channels to make the report. As stated earlier, the drawback with VTC is the excessive bandwidth requirements. With multi-bit rate codecs, the bit rate may be selected to accommodate the available channel capacity.

b. Intelligence Sharing

Videoteleconferencing can provide the efficient transfer of intelligence information to and from an afloat user. External surveillance cameras tied in with the VTC system may give an intelligence analyst critical information on the enemy's capabilities that a hard copy message cannot provide. The video is also provided on a real-time basis and eliminates the time delays experienced with developing the film and mailing photographs to the intelligence center. Once the intelligence data has been analyzed, the intelligence center can provide the on-scene commander a live briefing on the current threat based on his intelligence gathering efforts. Likewise, VTC provides the capability of receiving scheduled intelligence briefings transmitted from the various intelligence centers around the world. The afloat command can copy the relevant broadcast for his area of operation and record it for playback at a convenient time.

c. Other Afloat Applications

VTC applications for afloat users are not limited to command and control requirements or intelligence sharing. VTC can also be used for providing technical assistance, training, and pre-sail and post-exercise briefings.

Access to defense contractors is one feature that the Defense Commercial Telecommunications Network provides to its subscribers. This feature would be extremely valuable for an afloat user. Currently, an afloat unit conducting routine underway operations must submit an equipment casualty report that describes the nature of the problem. The report may also specify whether technical assistance is required and from whom. The Navy provides mobile technical units in the vicinity of standard fleet operating areas. These technical units receive the casualty reports and provide hard copy message assistance or make arrangements for transferring their representative to the afloat unit at the earliest opportunity. This procedure may involve excessive time delays and downtime for shipboard equipment. VTC may alleviate some of the time delay by providing real-time interactive video between the ship and the technical representative ashore. Problems, symptoms, and tendencies may be discussed to ascertain what trouble shooting steps to follow and recommended solutions to the problem. A mobile camera may also provide live video of the equipment to give additional information on the nature of the casualty.

The VTC capability may be extended to medical specialists for assisting at sea medical emergencies, weapons experts, negotiators, and many other types of consultants.

Shipboard training is also available through videoteleconferencing during in port and underway operations. The COMTRALANT Electronic

Schoolhouse (CESN) currently provides classroom instruction between the various training facilities along the East Coast. With VTC, afloat units may take advantage of training opportunities while underway by copying the training broadcast as a teleseminar or participating interactively, depending upon the available communications channel. Once onboard, the VTC signal can be fed to the wardroom, crew's lounge, or library to provide the necessary privacy.

Pre-sail conferences and post-exercise briefings may be conducted with VTC systems. A pre-sail conference conducted in Norfolk, VA, for example, could be transmitted to specified afloat units at their homeport locations. This capability negates travel requirements, increases the number of individuals who may participate, and improves productivity of individuals participating in the conference. Post-exercise briefings may be conducted between units during underway operations when the problems and highlights of the exercise are fresh in memory. This briefing may also include the immediate superiors ashore. Lengthy post-exercise messages may be reduced by discussing critical issues during the conference.

This section illustrated the applications of VTC for the afloat user in the areas of command and control, intelligence sharing, technical assistance, training, and scheduled briefings. Since VTC shows promise in enhancing a units ability to perform its mission regardless of the bandwidth requirements, it is important to establish a particular system that is compatible with user needs and

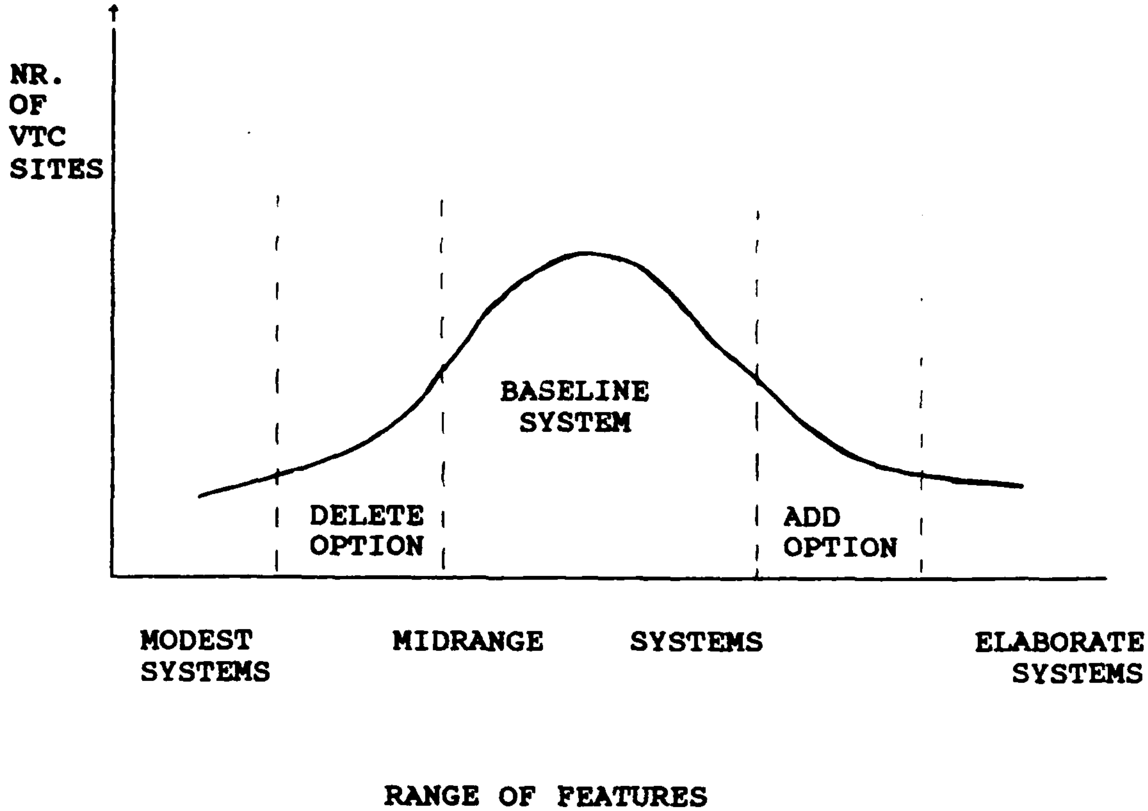
the limitations imposed by the at-sea environment. The next section describes the DOD baseline VTC system and the Multimedia Information Network Exchange (MINX) system that could fulfill the requirements of the afloat user.

C. THE AFLOAT VTC SYSTEM DESCRIPTION

1. The Purpose of Establishing a Baseline VTC System

A DOD VTC baseline system and options plan was developed by Keiper Associates to provide guidance on optimal VTC system design selection within the Department of Defense. The important issue involves a thorough review of performance specifications, -ather than the technical specifications. The use of performance specifications avoids the problem of over specifying a system design and supports flexibility in the areas of purchasing and system engineering. [Ref. 46:pp. 3-5]

The range of VTC system capabilities can be described as a bell shaped curve (See Figure 12). The mid-range systems encompass the baseline configuration with add-on and delete options. [Ref. 46:p. 6] The mid-range or DOD baseline configuration includes such items as voice switched cameras, one-half inch VHS VCR, high resolution graphics, echo controlled audio system with low profile microphones, and a VTC control panel on the conference table [Ref. 46:pp. 25-28]. VTC systems at the left hand side of the curve represent limited capabilities whereas systems on the right describe highly elaborate system



<u>BASELINE SYSTEM</u>

VOICE SWITCHED VIDEO
RESOLUTION GRAPHICS
W/ OVERHEAD CAMERA/SCANNER
REMBRANDT CODEC
NSA APPROVED ENCRYPTION
½" VHS VCR
CONTROL PANEL ON TABLE

<u>ADD OPTIONS FOR ELABORATE SYSTEM</u>

SECURE THREE WAY HIGH
CONFERENCING
SECOND CODEC AND CLI
ENCRYPTION DEVICE
SPILT SCREEN MONITOR
VIDEO
3\4" U-MATIC RECORDER/
PLAYER
VIDEODISC PLAYER
FACSIMILE
SECURE TELEPHONE UNIT

Figure 12. VTC System Capabilities

configurations. More elaborate systems may include split screen motion video for viewing multiple sites simultaneously, a second codec and encryption device,

secure simultaneous three way conferencing, and a second, separately addressable communications line. [Ref. 46:pp. 29-31] The complexity of the system depends upon the existing facilities or studio space available and the communications networking capability at the site.

The afloat user must select the appropriate level of complexity or number of options that will meet the requirements for connectivity and interoperability with shore facilities.

2. Baseline VTC Requirements and Options for Afloat Units

The baseline shipboard VTC system must accommodate the bandwidth limitations that exist when using military satellite systems and support the speed of connection, networking, security, multimedia, and system size requirements. As previously shown, multi-bit rate codecs are necessary to take full advantage of high resolution, near full-motion video at higher bit rates when increased channel capacity is available. When lower bit rates are required, 56 KBPS to 384 KBPS, the system must still provide acceptable picture resolution for the viewer. As mentioned in chapter two, the CLI Rembrandt codecs provide the multi-bit rate capability and the interoperability requirements that exist in current and planned DOD VTC applications. The added feature of the low bit rate system is that a fast dial-up capability could be available within a network that possesses the required software. In other words, a connection may be established by dialing a number similar to that used with the common telephone when calling another

subscriber on the network. [Ref. 47] This feature must be part of the VTC baseline to ensure quick access on command and control and intelligence sharing circuits.

The baseline networking mode should be secure point-to-point transmission. Security is provided by National Security Agency encryption devices that have built-in security status indicators and alarm systems to preclude inadvertent compromise of classified information. Point-to-point connections limit the number of participants in a conference during critical periods, but allow the system to function at lower bit rates with relatively simple switching requirements.

Space limitations aboard ship affects the size of the system selected for installation. Ideally, the VTC display components should be similar to that of a personal computer for desktop application. The control devices should be modular to facilitate distribution in various electronics spaces and for ease of system upgrades.

The afloat VTC system must provide a multi-media capability to the user. Multi-media information is characterized by four categories, voice, video, text and graphics. The video display component must provide the person's image and written text so that it may be reviewed during the conference. Simultaneous graphics display is essential to the afloat user due to space restrictions for large screen graphics displays. [Ref. 48:p. 47.4.1]

Miscellaneous components for the baseline system include video cameras, video camera recorders (VCR), and a system control panel. The video camera must be a high quality model that effectively filters out the noise portion of a video signal and operates in poor lighting conditions. In addition to the camera embedded in the desktop model, an external camera located on the ship's mast and a mobile camera must be included to provide video from locations outside the VTC room. The VCR is necessary to record a conference, and transmit an audio-visual tape of an event if live video capability is not available. The control system may be as simple as a computer keyboard which determines the video inputs to the VTC system as well as what information (video, graphics, or text) should be displayed during the conference.

VTC system options for the afloat user may include a point-to-multipoint connectivity using voice activated switching or split screen video, telepad capability, facsimile equipment, and large screen graphics display. Voice activated switching capability provides the video of the individual speaking during the conference to all other participants when three or more sites are connected. The person speaking is provided the video of the previous speaker. This concept has been called the virtual space approach, since it appears that the speaker and the audience are located in the same room. Split screen, the more complicated method, simultaneously displays up to six videoteleconference participants regardless of who is doing the talking. Telepad provides the capability to transmit

on-screen hand drawn accounts of an incident in conjunction with a video explanation of a particular situation. Telepad may be more appropriate than computer graphics in certain situations. Facsimile may be necessary particularly when the large screen graphics capability is not available.

3. The Multi-media Information Network Exchange (MINX) System

The MINX is a multi-media, full motion, color video workstation developed by the Datapoint Corporation. It was designed primarily for use with cheaper, switched 56 KBPS transmission service provided by major exchange carriers [Ref. 49:p. 49]. The MINX System appears to be well-suited for the afloat user since it meets the baseline VTC requirements and can accommodate options for enhancing system capabilities. Specific reasons for implementing the MINX system aboard afloat units include the following:

1. The MINX system is currently installed in existing military intelligence networks. The use of a CLI Rembrandt codec and the MINX system would ensure end-to-end interoperability between ship and shore facilities.

2. The MINX system supports both point-to-point and multi-point connections.

3. The MINX system is compatible with VCR equipment for recording and playback of conferences outside the VTC spaces.

4. The MINX system can be connected with other peripherals, including external surveillance cameras and large screen displays with speakers to accommodate larger audiences.

5. The MINX system can be connected to still motion cameras for transmitting imagery, charts, and slides.

6. The MINX system replaces a personal computer monitor that gives the system the ability to function as a personal computer, a VTC system, or

as a monitor for cable television transmissions. The integration of the personal computer allows the system access to files during the conference without disturbing the flow of the meeting.

7. The MINX system can operate effectively at various bit rates from near full motion video at 1.544 MBPS to limited motion at 56 KBPS, depending upon the available communications channel capacity.

8. The MINX system is modular in design, making equipment upgrades and replacement of faulty components a relatively easy task.

9. The MINX workstation is small enough to be used as a desktop model. Each workstation consists of a color monitor, a built-in color camera, a small monochrome viewfinder, a microphone, and a speaker.

10. Data encryption capability is available through the use of NSA approved devices.

4. A MINX System Configuration for Shipboard Use

The MINX system configuration described here will focus on a fleet flagship which has access to the Defense Satellite Communications System (DSCS). The primary components of the MINX system include the workstation, cluster server, cluster video adapter, and the codec. A baseline configuration would have two workstations installed, one located in flag spaces and the other workstation located in the Combat Information Center (CIC). Additional lighting may be required to improve the picture resolution. For CIC, the MINX would have to be placed on a desk with a curtain enclosure to avoid distracting watchstanders with the additional lighting requirements. The workstation provides a high resolution color monitor, a monochrome viewfinder that allows the user

to see how he appears on camera, a microphone, and a speaker. Workstation control is performed by a small keyboard similar to that used on a touch tone telephone. Each workstation should include a VCR, hard copy printer, and a personal computer with keyboard for graphics and file accessibility. Conversation privacy is provided by a secure telephone attached to the control keypad. [Ref. 50:pp. 5-6]

The cluster server, located in an electronics compartment, provides the automatic switching of video and audio signals. It is connected with the workstations and an external camera by cable television quality coaxial cable. One of the eight allowable slots in the cluster server is reserved for the cluster video adapter which is used for providing the necessary connection with the satellite communications link. The cluster video adapter has connections for video input and output, audio input and output, and control commands which is used for inter-cluster server signaling at a selectable rate from 1200 to 9600 baud. [Ref. 50:pp. 10-21]

Output from the cluster video adapter is sent to a CLI Rembrandt codec where the analog to digital conversion and data compression take place. Once the compressed data stream leaves the codec, it is encrypted by a KG-81 device and sent to the WSC-6 transceiver for transmission. Figure 13 provides an overview of the shipboard configuration.

Call processing with a MINX configuration is similar to that used with the standard dial telephone. An identification number is dialed into the control keypad for connection with other sites on the same network. In this case, the network used could be the Joint Worldwide Intelligence Communications System with connectivity provided by the DSCS III satellite. The MINX provides the capability to preview who the calling party is, so that a decision can be made whether to terminate the current conference or continue with a higher priority issue. The user must select the call or the connection will not be made. [Ref. 50:p. 9]

Multipoint capability is provided with a voice activated switching device. Only the current speaker's video is displayed for all participants. The person speaking sees the video of the previous speaker. This system does not, however, afford the opportunity for one participant to manually select and display video of one specific individual. [Ref. 50:p. 9]

D. INPORT AND UNDERWAY SCENARIOS INVOLVING VTC SCENARIOS

Videoteleconferencing systems can provide valuable information to higher authorities on critical situations involving afloat units. These scenarios assume that the JWICS network and the DSCS III satellite are providing the connectivity requirements between the flagship and the fleet command center ashore.

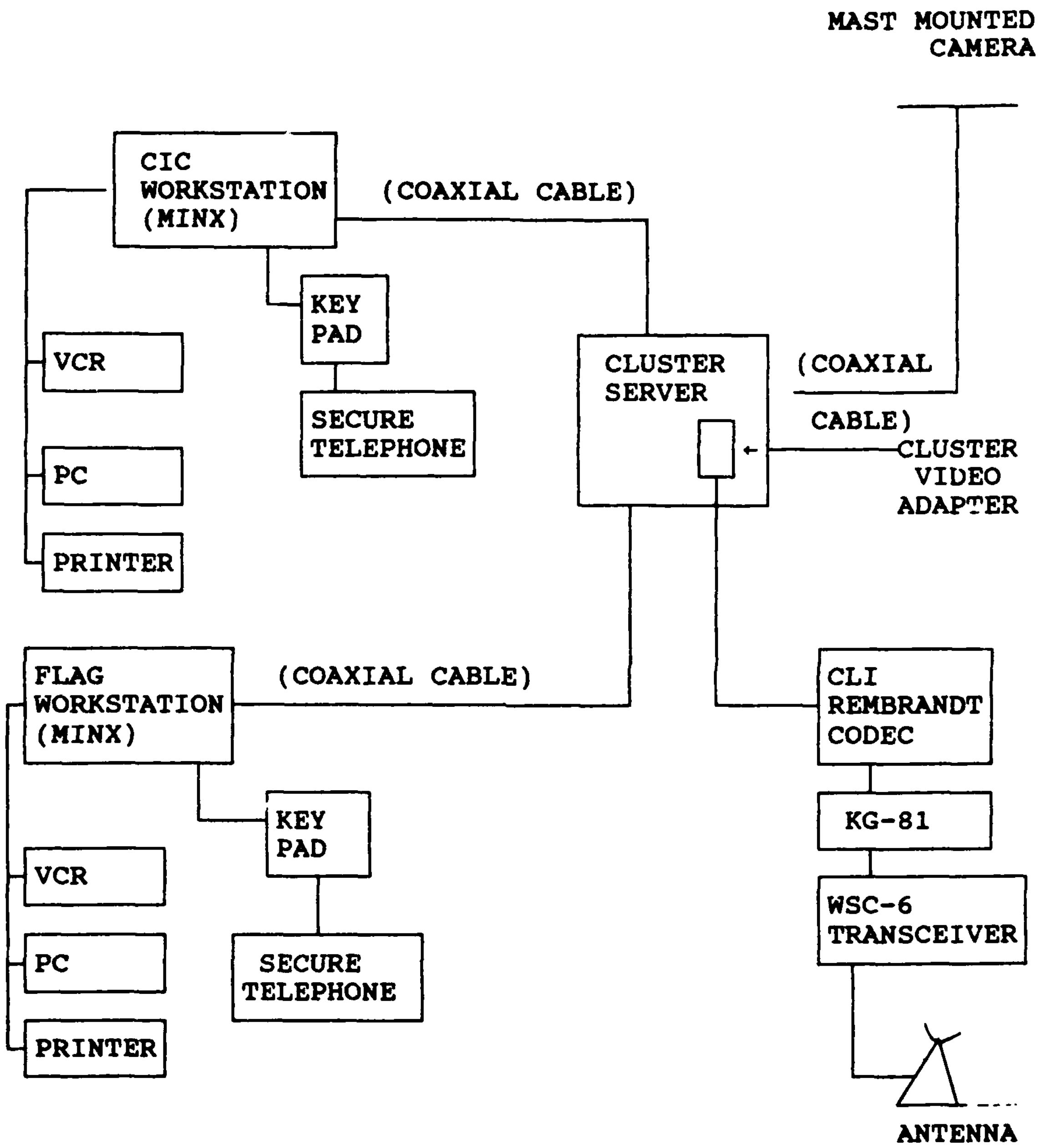


Figure 13. MINX Shipboard Configuration

The inport scenario begins with the flagship and supporting frigates and destroyers arriving at a resort town to help celebrate a national holiday. During the first day inport, one of the destroyers moored outboard the flagship experiences a major oil spill into the harbor while conducting a fuel oil transfer. The flagship, as senior officer present, decides to augment the initial voice and hard copy report of the incident with a videoteleconference between the ship and the fleet command center. The command center's identification number is dialed into the keypad and the point-to-point connection is made with the command center. The conference begins with a face-to-face discussion on the oil spill and cleanup status. The flagship then transmits live video of the spill surrounding the ship using the externally mounted mast camera. Movement control of the external mast mounted camera is provided by the workstation keypad. The graphics capability of the personal computer displays the approximate spreading of the oil slick on a rough drawing of the harbor. Finally, a file containing the proposed press release on the incident is called up from the computer and displayed on the screen. After review by the command center, the file is transferred to the command center and simultaneously prepared for transmission by the flagship to other commands via standard communication channels. The videoteleconference concludes and the recording is placed in storage for review by other concerned officers.

The underway scenario involves the flagship and escorts conducting a transit between port visits that takes them near waters claimed by an unfriendly third world country. During the transit, the ships encounter a fast patrol boat intercepting a merchant vessel of unknown registry in international waters. Spanish calls for help are heard over the bridge-to-bridge radio set. The flagship calls the fleet command center over the VTC network using the identification number and control keyboard. The information is reported on the intercept and assistance calls via face-to-face conversation. The ship closes the scene to provide live video of the situation via the mast mounted camera. The initial hard copy report on the incident is then displayed on screen for review by the command center. Coordination with the command center can be maintained throughout the incident and possible courses of action discussed while the live video is being transmitted.

E. CHAPTER CONCLUSION

This chapter provided information on what the afloat user requires in a VTC system. A VTC system must provide timely and accurate communications to support a wide variety of reporting requirements. The use of interactive video significantly enhances understanding of a situation at a distant location. More information is available to the decision maker in less time because formatted voice and hard copy messages transmitted over different channels are no longer required. Additionally, the ability to discuss strategy during a face-to-face

conference can result in a better understanding of the problem and improve the decision making process.

Specific applications of VTC systems in afloat units were provided in the areas of command and control, intelligence sharing, and briefings. The MINX workstation was described as one possible system that may meet the requirements of the afloat user. Finally, two scenarios were provided to illustrate how the MINX VTC system could be used during inport and underway operations.

The next chapter discusses the human factors behind the use of VTC systems. VTC systems provide a great deal more information than existing voice circuits, but some individuals may be hesitant to use it. The enhancement of information transfer, and personal dislikes for this relatively new communications technology will be discussed in detail.

V. INFORMATION RICHNESS AND THE HUMAN FACTOR

A. INTRODUCTION

Videoteleconferencing systems are one of many new technological advancements that were developed, based primarily upon technological and economic feasibility studies [Ref. 51:p. 101]. Recently, however, more emphasis is being placed on the human element in the design and implementation of new technology. This has led to a new area of research called ergonomics, which seeks to adapt work or working conditions to suit the worker. Ergonomics has become popular in the area of Management Information Systems (MIS) where improvements in workstation design and environment have resulted in increased individual productivity.

Videoteleconferencing systems fall in the category of Office Information Systems (OIS), which are specialized information systems used in the office environment [Ref. 52:p. 16]. However, VTC systems have also been described as a Managerial Support System or Communications Support System because of their unique ability to bring individuals together in a face-to-face meeting for discussing important issues and making critical decisions [Ref. 53:p. 170]. VTC systems are best used for complex problem solving and extensive information exchange in organizational situations that involve a significant amount of ambiguity or

uncertainty. The use of VTC systems for routine operational reporting is usually not appropriate [Ref. 54:p. 190].

This chapter discusses the richness of medium concept as it relates to VTC systems. Each communications media possesses a certain amount of richness which allows it to accurately convey information among individuals. The more significant the information and the greater the uncertainty in a particular situation requires a communications medium with greater richness. VTC systems provide a rich communications media as a close substitute for face-to-face meetings. This chapter concludes with a discussion of the human factors that may influence an individual's attitude toward using VTC systems.

B. RICHNESS OF INFORMATION AND THE COMMUNICATIONS MEDIUM

The distinction between information and data is important in the discussion of communications media richness. Data consists of facts or figures from which conclusions can be inferred. They are often compiled and stored in a computer database which can be updated and retrieved for various uses. Data is used extensively in the hierarchical command and control organization described in chapter four. Numerical values providing training and operational readiness status for individual afloat units are submitted to a central database for review by higher authorities. The data, once compiled and analyzed, indicate the unit's capability

to meet operational requirements. Without this analysis, the data provides little assistance to higher authorities in making critical employment decisions.

Information is data that has been processed into a meaningful form. Information tells the recipient something that was not known before and helps to reduce uncertainty or ambiguity in a given situation. [Ref. 52:p. A-16] Information comes in a variety of forms, including verbal and non-verbal language, touch, personal observation, and hard copy reports [Ref. 55:p. 304]. One individual's information may have little meaning to others. High level managers in all organizations require information vice data to evaluate the environment and make critical decisions on specific goals, objectives, and strategies.

The amount of information required by decision makers varies with the degree of uncertainty in a given situation. The inport and underway scenarios provided in chapter four both involve a certain degree of ambiguity. For the inport scenario, questions regarding possible environmental impact, weather conditions affecting oil spill cleanup, and public reaction to the spill may still require resolution. The underway scenario involving the fast patrol boat intercepting a merchant vessel is particularly difficult, because the exact intentions of the patrol boat are unknown and constant monitoring of the situation is required. In both situations, the amount of information required by the chain of command is significantly greater than that expected with a relatively routine operation. [Ref. 55:p. 306]

1. Information Richness

Information richness pertains to the amount of information that can be carried by a particular communications media. Face-to-face communications are the richest because they provide immediate feedback through verbal and non-verbal cues. [Ref. 56:p. 196] Non-verbal cues include eye contact, body movement, and facial expressions which make up approximately 93 percent of the message content transmitted during a face-to-face discussion [Ref. 56:p. 203].

Face-to-face discussions support early problem identification and group consensus on possible courses of action in a critical situation. The underway scenario involving the fast patrol boat and merchant vessel described in chapter four is just one situation where a face-to-face discussion could enhance the decision making process. The on-scene commander could provide all the relevant facts of the situation and then shift to an external camera for live action video of the situation if distance allows. The fleet command center, National Military Command Center (NMCC), and other conference participants would then have the capability of questioning the on-scene commander on specific matters that were not addressed in his opening remarks. Non-verbal cues observed by conferees could provide information on the stress factors that may influence the on-scene commander's decisions.

The equivocality or uncertainty of this situation has been sufficiently reduced by the use of a face-to-face conference [Ref. 56:p. 207]. Conferees now

share a common view of the situation and can proceed with developing various options to counteract any hostile action by the patrol boat. The final decision on specific courses of action can be reached by general consensus or other group decision making processes.

Radiotelephone and written documents are currently used to report incidents similar to the oil spill and fast patrol boat scenarios. However, telephone conversations and written documents do not provide all the cues that make face-to-face meetings an information rich communications medium. Radiotelephone conversations lack non-verbal cues and written documents are not timely and may oversimplify the situation.

The purpose of the initial voice report is to provide immediate notification of the incident to command centers so that procedures for handling the situation may be initiated. Initial voice reports on significant events are often hurried and lacking in specific details surrounding the incident. Additionally, the voice report may not provide an accurate initial assessment of the situation because of a lack of information and experience level of the caller. If the caller has not witnessed the incident, he must rely on others to provide him the information. He then collates and summarizes this information in the established reporting format. Without non-verbal cues, the recipient of the call cannot ascertain the stress factor or apparent experience level of the caller. This

inability to assess non-verbal cues may result in a misinterpretation of the situation by command center personnel.

The hard copy report is used to follow-up the initial voice report and provides amplifying details when possible. The problem with written incident reports is that they may be subject to an individual's interpretation of the situation. For example, the operations officer prepares the draft incident report based on personal observation or information provided by other individuals. As the draft message is reviewed by the chain of command, it is modified and released by the authorized individual. The actual incident report may not accurately reflect the seriousness of the incident primarily because of the personal interpretations of individuals involved in submitting it. Without the richness of face-to-face communications, the recipient is unable to question ambiguous or conflicting statements in the report. Immediate feedback is not available. Command center personnel must attempt to contact the unit on a voice circuit or hope that amplifying hard copy reports clarify the situation.

Videoteleconferencing systems provide the means for a face-to-face discussion of situations critical to national security and the safety or operational readiness of afloat units. Face-to-face discussions, augmented by actual video of the situation, would provide more information through non-verbal cues, personal observation, and timely feedback from other conferees. The ability to question on-scene commanders on issues not previously addressed enhances the conferees'

understanding of the situation and would help alleviate any ambiguity resulting from personal interpretation at the scene.

Figure 14 provides a summary of the different communications media and their associated characteristics. Face-to-face communications provides the greatest degree of information richness. However, the use of compressed video may cause some distortion in the non-verbal or body language area, particularly when a low data transmission rate is used.

Information Richness	Medium	Feedback	Channel	Language
High	Face-to-face	Immediate	Audio, Visual	Body, Natural
	Telephone	Fast	Audio	Natural
	Written/ Numeric	Slow- Very slow	Limited Visual	Natural/ Numeric
Low				

Figure 14. Communications Media Characteristics

The use of videoteleconferencing should be limited to situations that are critical in nature and involve a great deal of uncertainty. Using VTC for routine reporting requirements may result in confusion and misinterpretation of the information by conference participants. The confusion factor is caused primarily

by an excess of information. Routine readiness reports, for example, are not generally complicated. The presence of non-verbal cues may conflict with report content and cause misunderstanding on the part of the recipient. In general, routine problems do not require a rich communications medium to convey the information [Ref. 55:p. 308].

2. Information Richness in a Hierarchical Command and Control Structure

The command and control organization can be divided into top, middle and operational levels. Information richness is most important to top level management because they must contend with ambiguous situations that require timely decisions on objectives and strategy. The middle management level, however, is closer to the scene of action and may have a better understanding of the situation. Middle management also allocates resources and monitors the performance of subordinates. The operational units actually perform the missions as assigned by higher authority. Information richness is not as critical at the operational level of the hierarchy and tasking is normally provided as written correspondence in the form of operational procedures, plans, or tasks.

Top level management of an organization often holds group meetings, an information rich medium, to exchange opinions, perceptions, and judgments face-to-face. Videoteleconferencing provides top level management the capability to hold group meetings when conferees are located in widely separated geographical locations. The advantage to group meetings is that a shared common

view of a situation can be obtained relatively quickly. Once a course of action has been determined, tasking for operational units may be transmitted as written correspondence or electronic mail. This less rich communications media is acceptable since most of the ambiguity in the situation has been eliminated by richness of information used at higher levels of authority during the decision making process.

In summary, the use of videoteleconferencing capabilities in an at-sea environment could provide a communications media with more information richness than the voice and written correspondence methods in use today. VTC systems provide the means to link widely separated individuals together in a face-to-face meeting for reducing ambiguity in a critical situation. Once the particular course of action has been determined, a less rich communications media may be used to direct individual units toward a specific objective. However, the use of VTC systems also involves other human factors that must be considered prior to implementation. These factors may hinder videoteleconferencing's acceptance as a viable substitute for face-to-face meetings and incident reporting in general.

C. HUMAN FACTORS

Human factors ultimately determine whether a particular system is accepted by the end users. Since VTC systems involve a relatively new technology with video images of participants, a great deal of apprehension, resistance to change, and feelings of lost privacy may develop. Afloat users may also feel a decrease

in freedom of operation with VTC systems because of the ease of access provided to superiors. This section discusses these human factor issues and how they relate to videoteleconferencing systems.

1. Voice Switched Video or Continuous Presence

One of the critical human factors influencing the acceptance of VTC systems is the continuous presence of all conference participants at each site. The continuous presence capability provides the feeling of meeting in a true face-to-face environment. Participants are comfortable with continuous presence because they see all other conferees simultaneously. Everyone's non-verbal cues are viewed, not just the previous speaker. [Ref. 21:p. 19.3.3]

The baseline afloat VTC system described in chapter four uses a voice activated switching capability for multipoint conferences. The video image of the person speaking is transmitted to all participants except the current speaker, who receives the video of the previous speaker. The voice activated switching would be used to conserve bandwidth on available satellites. Continuous presence is normally provided by increasing the number of video monitors or splitting one monitor to provide video images of all participants simultaneously. [Ref. 21:p. 19.3.3]

Continuous presence capability would be difficult to provide at sea due to the large bandwidth it requires. As a result, the human factor must be compromised in order to provide any VTC capability to ships at sea. However,

this compromise may not be significant to all users because the evaluation of VTC systems is highly subjective and governed primarily by individual preferences. What is acceptable to one person may not be for another. This is true for continuous presence capabilities as well as data rates and picture resolution.

In conclusion, continuous presence is an essential feature foı enhancing the conduct of a videoteleconference. However, the use of voice activated switching is an acceptable and necessary method when available bandwidth is limited.

2. Freedom of Operation

VTC systems may provide higher authorities more control over the actions of subordinate commands. A commander's superiors would have the capability to view the situation and make decisions for the on-scene commander. This process could result in a reluctance of commanders to make decisions without consulting higher authorities first [Ref. 53:p. 171]. At-sea commanders r ..st still retain a certain sense of autonomy to perform effectively under adverse conditions and particularly when counsel with superiors is not feasible. Superiors must avoid the temptation to micro-manage a situation now that videoteleconferencing provides them with greater access to information.

3. Information Overload and Communications Stress

VTC systems provide a rich communications media as a close substitute for face-to-face meetings. However, VTC systems may also be responsible for

increasing the communications stress factor. Communications stress is caused by an increase in information throughput rather than a reduction in total time spent on a set volume of information. As a result, individuals at higher levels of authority may shy away from VTC, particularly when the discussion involves routine problems. Therefore, VTC systems should be limited in use to those situations involving a significant amount of ambiguity to justify the amount of information passed over this medium. Communications stress and information overload would be minimized by limiting the use of VTC to situations involving national security and operational readiness issues. [Ref. 51:pp. 107-108]

4. The Privacy Issue

Videoteleconferencing provides a new window for viewing an individual's actions and working environment. The ordinary telephone, in contrast, allowed the individual some secrecy in terms of personal appearance and activities like doodling and gesturing to others during a conversation. With VTC systems, particularly desktop models, participants must be aware of the importance of non-verbal cues and their office environments when participating in a conference. A quickly arranged conference may result in an unacceptable appearance in front of other participants. To alleviate this problem, some VTC systems provide a preview capability that allows individuals to screen calls prior to acceptance. Non-urgent calls may be placed on hold until the individual's workspace is presentable for the conference. [Ref. 51:p. 102]

5. Physical Appearance

Some VTC participants may feel a certain degree of self-consciousness about their appearance on a video screen [Ref. 51:p. 104]. The use of lower data rates and relatively poor picture resolution may compound the personal appearance problem. Most VTC systems provide a capability for the individual to view his own appearance as it is seen by other participants. This allows him to correct what he may perceive as an unacceptable appearance on camera.

Human factors must be considered when implementing new technologies within an organization. The key to successful VTC system implementation is to educate end users in the technical and operational characteristics of the system, and thus overcome the apprehension and resistance to change that is involved in introducing new technologies.

D. CHAPTER CONCLUSION

Videoteleconferencing systems provide a communications medium that is rich in information transfer among participants. VTC represents a close substitute for face-to-face or group meetings. This enables individuals to view non-verbal cues that may help reduce the ambiguity of a situation and make the decision making process much easier. However, the use of VTC systems also represents significant human behavioral considerations that may affect system acceptance by end users. Only through a dedicated education program can these problems be overcome and full implementation of the system realized.

VI. CONCLUSION

A. INTRODUCTION

The purpose of this study was to determine the feasibility of implementing videoteleconferencing systems aboard afloat naval units. Research into the feasibility question centered on the use of existing satellite systems, and existing, or planned DOD videoteleconferencing networks, to fulfill the necessary connectivity requirements. Following the feasibility study, an attempt was made to determine if a requirement for VTC exists in an at-sea environment, and what specific needs it could fulfill. A proposed VTC system design was described using equipment currently in use within DOD VTC networks today. Finally, the advantages and disadvantages were discussed based primarily on the information richness of face-to-face meetings and human factors affecting the acceptance of VTC systems.

B. CONCLUSIONS

The use of VTC systems aboard afloat units is feasible with existing military satellites. Low data rates provided by compatible codecs at the conference sites is essential for maintaining interoperability and conserving satellite transponder bandwidth.

The Defense Commercial Telecommunications Network, however, would not support the connectivity requirements for an at-sea conference site. Future implementation of the JWICS VTC Network should provide the necessary features for establishing a ship-shore videoteleconferencing capability.

VTC has various applications for shipboard use. These include the enhancement of operational reporting procedures, intelligence sharing, and tactical planning. The MINX system produced by the Datapoint Corporation is one system capable of supporting VTC aboard ship.

Videoteleconferencing provides the information richness of a face-to-face meeting. Information richness is extremely important at the top level of the chain of command because of the significant amount of ambiguity experienced in critical situations. However, overcoming the human factors, particularly concerns over continuous presence, physical appearance, and freedom of operation is critical to the acceptance of VTC as a means of communication.

C. SATELLITES AND NETWORKING

The FLTSATCOM and DSCS III military satellite communications systems were evaluated based solely on transponder capacity. The FLTSATCOM is a UHF system providing narrow band services to afloat units. The narrowband transponders are heavily allocated for tactical networks and could not be effectively used for videoteleconferencing. The wideband channel has the capability to provide near full motion video. However, use of this transponder

would require reallocation of existing communications circuits. In both cases, narrowband and broadband transponders, the data rate is dependent on the type of phase shift keying employed.

The DSCS III satellite system would be the preferred transmission channel for videoteleconferencing. The DSCS III system is a SHF capable satellite that can provide wideband services to afloat units with the WSC-6 transceiver installed. The problem with using the DSCS III system is that it limits the number of VTC users to those having SHF equipment installed. Once again, compromises on circuit allocation would be required because of the wideband requirements with VTC systems.

Videoteleconferencing networks currently used by DOD agencies were evaluated for interoperability with afloat units. The Defense Commercial Telecommunications Network (DCTN) would not be the network of choice for two reasons. First, the DCTN primarily supports large shore facilities with sophisticated studios and high data rate requirements. High data rates, particularly 1.544 MBPS, would not be available with the limited bandwidth and circuit priorities that exist with military satellites. Secondly, the DCTN uses commercial satellites. This would require the installation of additional communications equipment aboard afloat units.

The projected capabilities of the Joint Worldwide Intelligence Communications System (JWICS) VTC network show promise for interoperability

with afloat units. JWICS will provide quick network access via a dial up service, a precedence feature and connectivity with intelligence and fleet command centers. The Multimedia Information Exchange (MINX) system produced by the Datapoint Corporation is the VTC system planned for JWICS. The MINX system could be used aboard ship because of its small size, modularity, and interoperability with JWICS.

D. USER REQUIREMENTS

Videoteleconferencing systems could support timely and accurate incident reporting, intelligence sharing and tactical planning. A videoteleconferencing system with dial up service could provide a command center with more accurate and timely information on a critical situation than the standard voice and hard copy reports used today. Live video of a particular intelligence collection target could enhance intelligence reporting and reduce the required analysis time. Finally, videoteleconferencing could improve tactical and strategic planning by involving the senior commanders at-sea in face-to-face briefings on the employment of assigned forces.

E. INFORMATION RICHNESS AND THE HUMAN FACTOR

Videoteleconferencing provides a close substitute for information rich face-to-face meetings. Information richness is extremely important to the higher echelons in a hierarchical organization because of the ambiguity or uncertainty

surrounding critical situations. With VTC, on-scene commanders could provide live video as well as non-verbal cues to command centers on the exact nature of the problem. The richness of this information could assist top level management in making well informed decisions on critical situations.

The acceptance of videoteleconferencing as a viable communications media is hampered by human factors. Many design features have been implemented in VTC systems to overcome a person's reservation about this new technology.

F. FURTHER RESEARCH

Further research is required in the networking and connectivity requirements for JWICS, the cost-benefit of VTC, and the human factor issue. For JWICS, the question is whether military or commercial satellites will be selected as the transmission media. If military satellites are used, will the necessary hardware and switching equipment be available for meeting the connectivity requirements for afloat units?

The cost-benefit analysis should be performed to determine if the benefits of having VTC outweigh the costs. The difficulty with a cost benefit analysis is in quantifying the intangible benefits such as information richness and comparing it to the hardware costs.

Research into human factors is required to improve the user friendliness of VTC systems. The use of ergonomics should continue to provide improvements that make videoteleconferencing an accepted communications medium.

G. RECOMMENDATION

The JWICS VTC network appears to be well-suited for connecting afloat units and command centers for videoteleconferencing. The author recommends that an operational evaluation be conducted to determine the interoperability between JWICS and a flag configured unit, when JWICS completes full implementation.

APPENDIX A

USEFUL ACRONYMS AND ABBREVIATIONS

ADP	Automated Data Processing
ASD	Assistant Secretary of Defense
AT&T	American Telephone and Telegraph Company
AUTOVON	Automatic Voice Network
C	Comptroller
CAP	Contractor Access Point
CCITT	International Consultative Committee on Telegraphy and Telephony
CDRWESTCOM	Commander Western Command
CESN	Comtralant Electronic Schoolhouse Network
CIC	Combat Information Center
CINC	Commander-in-Chief
CLI	Compression Labs Inc.
CODEC	Encoder/Decoder
COI	Community of Interest
COMTRALANT	Commander Training Command Atlantic
COMTRAPAC	Commander Training Command Pacific

CONUS	Continental United States
COTR	Contractor Technical Representative
C3I	Command, Control, Communications and Intelligence
DAMA	Demand Assigned Multiple Access
DARPA	Defense Advanced Research Projects Agency
DCA	Defense Communications Agency
DCS	Defense Communication System
DCTN	Defense Commercial Telecommunication Network
DDI	Duty Director of Intelligence
DDN	Defense Data Network
DES	Digital Encryption Standard
DIA	Defense Intelligence Agency
DOD	Department of Defense
DPC	Data Protocol Converter
DPCM	Differential Pulse Code Modulation
DSCS	Defense Satellite Communication System
DSN	Defense Switched Network
ECMC	Enhanced Crisis Management Capability
EUCOM	European Command
FDMA	Frequency Division Multiple Access
FEC	Forward Error Correcting

FLTSATCOM	Fleet Satellite Communication System
FORCECOM	Forces Command
FSK	Frequency Shift Keying
GHZ	Gigahertz
HF	High Frequency
HQPACAF	Headquarters Pacific Air Force
INMARISAT	International Maritime Satellite
IPAC	Intelligence Command Pacific
ISDN	Integrated Services Digital Network
JCS	Joint Chiefs of Staff
JWICS	Joint Worldwide Intelligence Communication System
KBPS	Kilo Bits Per Second
KHZ	Kilohertz
LEASAT	Leased Satellite
LCM	Life Cycle Management
MARISAT	Maritime Satellite
MBPS	Mega-Bits Per Second
MHZ	Megahertz
MILSATCOM	Military Satellite Communication System
MINX	Multi-media Information Exchange Network
MIS	Management Information System

NAVCAMS	Navy Communications Area Master Station
NATO	North Atlantic Treaty Organization
NAVAIR	Naval Air Systems Command
NAVSEA	Naval Sea Systems Command
NAVSUP	Naval Supply Command
NCA	National Command Authorities
NCAMS	Network Control and Alarm System
NMIC	National Military Intelligence Center
NTSC	National Television Standards Committee
OIS	Office Information System
OSD	Office of the Secretary of Defense
PA	Public Affairs
PACOM	Pacific Command
PC	Personal Computer
PLN	Private Line Network
PMO	Program Management Office
PSK	Phase Shift Keying
SCI	Sensitive Compartmented Information
SCP	Sessions Control Panel
SHF	Super High Frequency
SSMS	Special Services Management System

SVTS	Secure Video Teleconferencing System
TASNSC	Teleconferencing Activities, Systems, and Network Steering Committee
TDMA	Time Division Multiple Access
TSR	Telecommunications Service Request
UHF	Ultra High Frequency
URDB	User Requirements Database
USCINCPAC	United States Commander-in-Chief Pacific
USFK	United States Forces Korea
USPACOM	United States Pacific Command
VCC	Video Conference Controller
VCR	Video Camera Recorder
VI	Visual Information
VLSI	Very Large Scale Integrated Circuits
VPLN	Virtual Private Line Network
VSAT	Very Small Aperture Terminal
VTC	Videoteleconferencing
WATS	Wide Area Telecommunications Service
WWMCCS	World Wide Military Command and Control System

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